RENEWAL OF MILWAUKEE AVE. VIADUCT

BY
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ARMOUR INSTITUTE OF TECHNOLOGY

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Renewal of the Milwaukee
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THESIS

THE RENEWAL

OF THE

MILWAUKEE AVENUE VIADUCT,

Presented By

Seymour C. Anderson

William E. Beach

to the

PRESIDENT AND FACULTY

of the

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for the degree of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING,

having completed the prescribed course of study

in

CIVIL ENGINEERING

1912

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THE RENEWAL
OF THE
MILWAUKEE AVENUE VIADUCT.

PLATE 21. Typical cross section of girder.

" 22. Design of concrete slabs.

" 23. Design of concrete beams.

" 24. Design of concrete girders.

" 25. Design of " " (continued)

" 26. Shear diagram and stirrups for girder

" 27. Design of side girders.

" 28. Design of girders in bents.

" 29. Shear diagram and stirrups for bent girders.

" 30. Design of concrete columns.

" 31a. Shear diagram for column foundation.

" 32. Design of concrete column foundation.

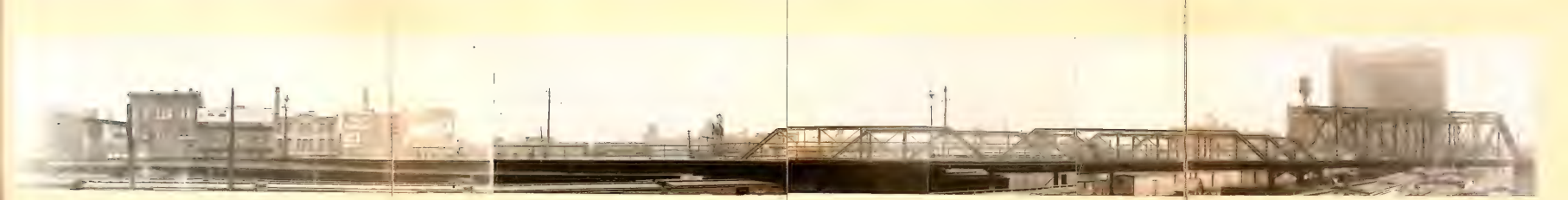
" 33. Plan view and sections of concrete.

" 34. Design of rail fastening in concrete.

" 35. General Survey of viaduct

" 36. General plan and elevation of structure.

VIEW OF VIADUCT. (Looking East)



VIEW OF VIADUCT. (Looking East)

VIEW OF NORTH APPROACH. (Looking South)

VIEW OF PONY TRUSSES (Looking South)

VIEW OF SOUTH APPROACH. (Looking North)

The Renewal of the Milwaukee Avenue Viaduct.

Part I.

This viaduct is located along Milwaukee Avenue, its northern terminal being Kinzie Street and its southern, Carroll Avenue. It spans the tracks of the Chicago and Northwestern, the Chicago, Milwaukee and St. Paul, and the Pennsylvania R. R's.

The primary reason for renewal is, that first it is too light a structure to adequately accomodate the street and car traffic to which it is continually subjected; and secondly, it allows too little clearance for the railroad freight traffic. When the present structure was constructed the street and car traffic was, as compared with now, very much smaller. This is especially true of the street cars. The thru structures of the present system are only heavy enough to support one of the cars used at present, at a time. Again, the increased freight traffic has caused the increased size of freight cars, this resulting in decreased clearance under the structure.

The present viaduct, beginning at the north abutment, consists of: eight spans of deck plate girders of various lengths, two of thru Pony trusses

and one of an over-head braced thru truss. To counteract the existing conditions as set forth in the previous paragraph, the proposed structure will be made heavier, the grade will be slightly raised and the floor system made shallow; the effect of the last two being to increase the clearance of the railroad traffic. In selecting a suitable structure for the place the following items will be briefly considered, viz. (1) the cost and time of construction, the (2) delay to traffic; both freight and street; and (3) its appearance from an aesthetic point of view.

First, the cost of construction. There are numerous types of structures that might be considered. The span of the viaduct is approximately six hundred and seventy feet in length.

(a) A THRU OVERHEAD BRACED STRUCTURE.

(1) In considering a structure of this type there would have to be at least three spans. For example then, consider the span length two hundred and twenty feet long. The ordinary type of floor beams extending from panel point to panel point could not be used on account of the clearance necessary. The only floor system that could be used will be a shallow one, consisting of a

trough system, or I-beam spaced closely on centers. A girder of the thru plate type would be necessary tp attach either one of these systems to, the girders being supported at the panel points. Summing up this type of construction then, means that there is a system of thru plate girders superimposed upon an overhead braced structure. It is obvious that this type of construction would be very heavy and consequently costly . A simple thru plate girder could be used to better advantage.

The time of construction of such a structure would be longer than that taken to construct a simple thru girder type. As the time element is one of cost as regards construction and inconvenience and congestion as regards street traffic, a type which would require less time to construct would obviously be cheaper.

(2) The construction of such a type as has been previously considered would require a substructure. A specially designed substructure would have to be designed in order to reduce the delay to freight traffic to a minimum. Even at its best, freight traffic would be considerably delayed, a fact which when considered alone wouldlead one to consider a type more feasible of construction.

(3) The appearance of such a structure would not be pleasing in such a place. It would look cumbersome and awkward.

B. A DECK PLATE SYSTEM.

(1) To acquire sufficient clearance the depth of girders would have to be small. This means that they will have to be spaced closely together on centers; thus requiring quite a number of girders to a span. Considering the depth, the spans could not econoomically be made much more than thirty feet. That means about twenty three spans. As the depth varies about one tenth of the span length it will be approximately three feet. Assuming that the minimum spacing of girders to be about six feet, in a roadway of sixty six feet, twelve girders would be necessary or a total of about two hundred and seventy-six girders. The total weight of all this steel would be considerable and costly. Here again a thru plate girder would be more economical.

The time of construction would be less than that required for the type considered under "A" but the cost factor would discard it in view of the fact that another type would be more economical.

(2) The construction of this traffic, especially freight would be slight, because it could be built from the street grade by means of a movable hoist.

(3) It would be a better appearing structure than the former and approaches more closely an open structure, a fact which is being clearly kept in mind in the selection of a suitable structure.

C. A REINFORCED CONCRETE STRUCTURE.

(1) While a reinforced structure would be cheaper than either of the two preceding types there are other things to be considered. This structure would be better and more lasting, the cost of up-keep being reduced to a minimum.

The time of construction would be about the same as that required for the previous ones. This is so, because it could only be built in sections, the reason for which is stated in the following paragraph which treats on the delay to traffic.

(2) The one serious factor against the selection of this type is the delay to freight traffic. A substructure must necessarily be built to construct this type and said structure would ne delaying traffic at point of construction until the concrete had thoroughly set. At points on construction the substructure

would tie up the traffic completely and so compromise the rearrangement of the traffic on the free tracks that an over amount of congestion would occur.

(3) The appearance of such a structure would be very pleasing, both at close and long range. It would be a type that would beautify the place and make traveling light and easy. Outside of the delay to freight traffic there is no onjectionto the choice of such a structure.

In the construction of these classes the delay of the street traffic has not been considered very carefully, because it was assumed that the majority of it would be transferred to Desplaines Street at Kinzie Street.

D. A THRU PLATE GIRDER STRUCTURE COMBINED WITH REINFORCED CONCRETE.

(1) Here thirteen spans were considered,ten consisting of thru plate girders and three of reinforced concrete. Six of the ten girder spans were assumed to be fifty-two feet long, and the two remaininh, sixty feet in length. Three girders were assumed to each span, making a total of thirty girders. The floor system was made shallow by the use of I-beams spaced

closely on centers. This type of construction was found to be most economical due to the lesser weight of steel and building materials. The floor system of the concrete spans at the north end was made shallow by spacing the girders five feet on centers and using cross beams five feet centers making a slab five feet square.

The time of construction would be reduced to a minimum because of lesser steel construction in the field. This is so because the construction could be started from both ends and work toward the center, thus cutting the time approximately by half.

(2) The only delay to the railroad traffic would be at the northern terminal where the concrete spans are to be located. This would only stop the traffic on three tracks at the most and this could easily be adjusted for the time being. The girder spans would be constructed from overhead, no substructure therefore being necessary. So as far as delayed traffic is concerned this type of construction would be the most feasible as compared with the previous types.

(3) While the appearance of the steel girders is not exactly prepossessing, a means of obviating

this was in the assumption of a concrete veneer, around each one. This on the whole makes a better appearing structure than the concrete structure would, because the girders would be of less depth.

Therefore, the most suitable type of construction is the last named and the following design will include this type of structure.

PART II.

Design and specifications for a combined thru plate girder and reinforced structure.

The reason for making the northern terminal of reinforced concrete is because the girders cannot be carried to the abutment at said point, The effect of such, i.e. bringing them to the north abutment would be to cut off the approach to Desplaines Street, this fact making that construction impossible.

A comparison of the present system and the proposed system will now be set forth. The present system consists of a ninety foot thru overhead braced structure at the south, then two thru Pony trusses, and a series of deck plate girders, the spans of which vary from fifty to sixty feet. The total is approximately six hundred and sixty feet. The arrangement of

of the proposed system which has been hinted at is in detail as follows. Beginning at the south abutment, there will be two fifty-two foot girders, then two sixty foot girders, the location of Pier #3 being unchanged, then six fifty-two foot spans of girders and finally three concrete spans at the north end, each forty-three feet and eight inches in length.

The total width of the viaduct will be made sixty-nine feet and six inches. Throuout the girder spans, the street and walk will be supported by three girders, one situated between the car tracks and the remaining two between the side walk and street.

On this account two girders will have to be designed for each of the two spans. This is so because the central girder takes a heavier load due to the moving load of the cars than do the side girders and consequently have to be of heavier section. The girders were assumed as nearly uniform in length as possible so as to reduce the cost of shop construction. The floor system which was designed shallow consists of 15"I beams spaced two feet on centers. This part of the structure was made solid and rigid by placing concconcrete filler between I beams, the surface of which

was made flush with the tops of the I beams. The car rails the depth of which is seven inches are attached directly to the I beams. Upon the remaining surface of the street a three inch sand cushion was figured and firmly tamped. The surface of the street was figured up to grade by using creosote blocks four inches deep.

The width of each roadway is twenty seven feet and each sidewalk six feet clear space. The walk is supported on cantilevers spaced six feet on centers. The walk proper consists pf a five inch reinforced slab.

The stresses in th girder were obtained as follows. A special loading shown in plate #1 was used to figure the live load moments and shears for the sixty foot girder. The bending moment and shears were obtained fot the same girder from Cooper's E-40 and E-50 loading and ratios were made between the respective moments and shears respectively, i.e. Cooper's two loadings were compared with the special loading used. The moments and shears in the two remaining spans were obtained by multiplying the maximum moments and shears as given in Cooper's loadi ngs by the constant ratios

derived. For the remaining roadway the live loading was assumed to be one hundred pounds per square foot. The equivalent uniform loadings shown on plate II were obtained from the following formalue.

$$M \quad \frac{wl^2}{8}$$

M maximum live load moments

l span length in feet

w weight per lineal foot.

The dead load per lineal foot included the following items: the weight of the creosote block,; the sand; the rails; the floor beams; the concrete filler; the cantilevers; the weight of the girders and the weight of the concrete veneer. The dead weight of the girders was figured from the formulae:

w aLb

w weight per lineal foot

a aconstant 12.5

L span length in feet

b a constant 200

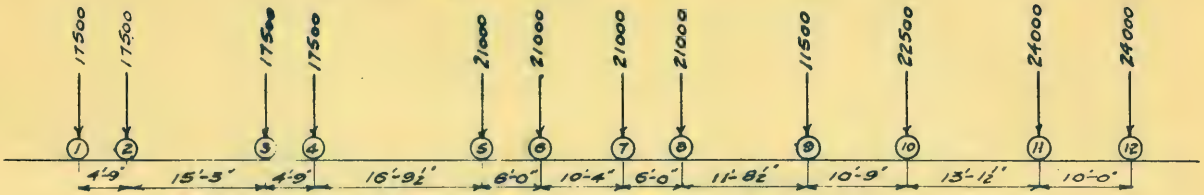
Twice this valve or 2w was taken as the weight per lineal foot of the central truss because it supports part of each street and is therefore of heavier cross section. The live and dead loads assumed for the walk were taken as one hundred and seventy five

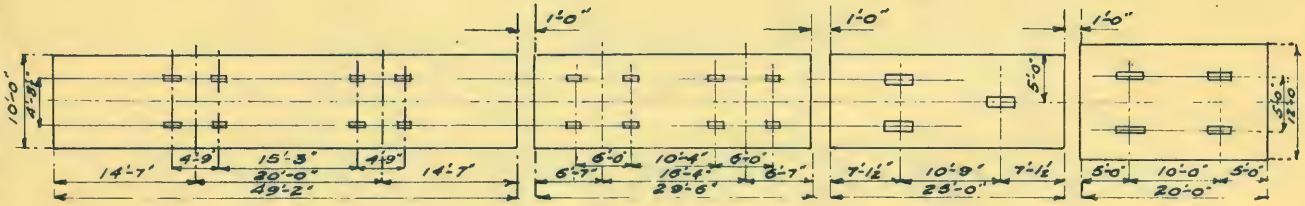
pounds respectively.

The girders shall be braced laterally against the wind pressures and be supported on columns, the bracing of which shall be at least four times the required section. The columns shall be designed to take the total end shear transmitted from the adjacent girders.

The American Railway Engineering and Maintenance of Way Association specifications, second edition, 1910, governed the design of the steel work and for the reinforced concrete work Turneaure and Maurer's "Principles of Reinforced Concrete"was used.

LOADING USED BY THE CITY OF CHICAGO
BRIDGE DEPARTMENT





STREET CAR
35 TONS

SPRINKLER
42 TONS

STEAM ROLLER
17 TONS

HEAVY WAGONS
24 TONS

SPECIFICATIONS:- CITY OF CHICAGO BRIDGE DEPARTMENT FOR SINGLE TRACK 1-35 TON STREET CAR FOLLOWED BY 1-42 TON SPRINKLER CAR FOLLOWED BY 1-17 TON STEAM ROLLER FOLLOWED BY AS MANY 24 TON WAGONS AS CAN BE PLACED ON REMAINING SPAN.

SCALE 1"=15'-0"

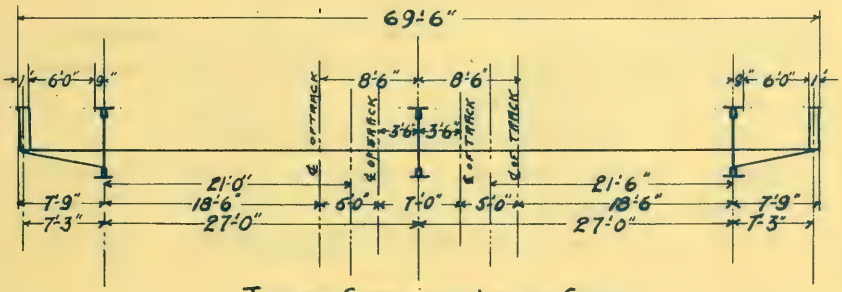
S.C.A.

PLATE 1

LIVE LOAD MOMENTS and SHEARS.

NOTATION		60'-0" SPAN	52'-0" SPAN
CHICAGO BRIDGE LOADING	MAXIMUM MOMENT	844.4 K.F.	665.0 K.F.
	END SHEAR	79.7 K.	72.9 "
	1/4 POINT SHEAR	49.2 K	44.75 K
	1/2 POINT SHEAR	22.7 K.	20.5 K.
COOPER'S E-50	MAXIMUM MOMENT	3245.0 K.F.	2540.0 K.F.
	END SHEAR	244.0 K.	222.7 K.
	1/4 POINT SHEAR	150.4 K.	137.0 K.
	1/2 POINT SHEAR	69.4 K.	62.6 K.
COOPERS E 40	MAXIMUM MOMENT	2540.0 K.F.	2030.0 K.F.
	END SHEAR	195.2 K	178.5 K
	1/4 POINT SHEAR		
	1/2 POINT SHEAR		
RATIO U.L. TO U.L. FOR 60'-0" SPAN E-50	MOMENT		0.26
	SHEAR		0.327
E 40	MOMENT		0.325
	SHEAR		0.407
EQUIVALENT LIVE LOAD PER FOOT.		1875	1963

DATA.										
Width of Bridge	Walk Width	Street Width	Width outside Track.	Lbs./□' on Street	Lbs./□' on Walk.	Load on Street.	Load on Walk.	Weight to Central	Weight to Side	Span Length
69'-6"	6'-0"	27'-0"	22'-0"	100	100	132 K.	36 K.	803.65 K.	2746.5 K.	60'-0"
69'-6"	6'-0"	27'-0"	22'-0"	100	100	110 K.	30 K.	803.65 K.	2746.5 K.	52'-0"



TYPICAL CROSS-SECTION OF STREET.

SCALE:- 1" = 12'

Span	Central Girder				Side Girder.			
Length	Total Live Load Moment	Total Live Load Shear	Total Live Load ¼ Pt. Shear	Total Live Load ½ Ft. Shear	Total Live Load Moment.	Total Live Load End Shear	Total Live Load ¼ Pt. Shear	Total Live Load ½ Pt. Shear
60'-0"	2036.8 K.F.	172.15 K.	100.65 K.	35.0 K.	1427.5 K.F.	100.2 K.	52.15 K.	5.05 K.
52'-0"	1578.8 K.F.	155.2 K.	90.54 K.	31.9 K.	1077.6 K.F.	87.8 K.	45.73 K.	4.55 K.

WEIGHTS OF STREET MATERIALS, LOADING AND CLEARANCES.

CREOSOTE BLOCK (DEPTH) 4" } RAIL (DEPTH) 7"
SAND CUSHION (") 3" }
I-BEAM-FLOORBEAM (") 15"
GIRDER FLANGE (") 8"
TOTAL..... 30" = 2'-6"

THE RAILS ARE ATTACHED DIRECTLY TO THE FLOORBEAMS.

THE CONCRETE FILLER IS FLUSH WITH THE TOP FLANGE OF THE FLOORBEAM.

WEIGHT OF SAND / CUBIC FOOT = 118 LBS.

" " CREOSOTE BLOCK = 12 x 4.5 + 10 (FOR TREATMENT) = 64 LBS.

DEAD LOADING ON CENTRAL TRUSS.

CONCRETE FILLER = 27 x 125 =		3,380 LBS.
WEIGHT OF RAILS (TO CENTER) =	75 x 18.5 + 75 x 23.5 / 27	232 "
" " SAND =	27 x 0.25 x 118	800 "
" " CREOSOTE BLOCK =	27 x 0.33 x 64	575 "
ASSUMED WEIGHT OF CONCRETE VENEER =	6 x 150	900 "
	TOTAL	5,882 "

$M = \frac{wl^2}{8} = \frac{5,882 \times 3,600}{8} = 2,640,000$ FT. LBS.

END SHEAR = $\frac{60 \times 5,880}{2}$ = 176,000 LBS.

¼ POINT SHEAR = $\frac{176,000}{2}$ = 88,000 LBS.

½ POINT SHEAR = 0000.00

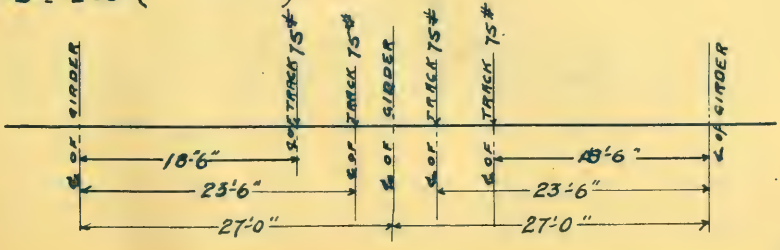
DEAD LOAD PER FOOT OF GIRDER FIGURED FROM FORMULAE

W = AL + B.

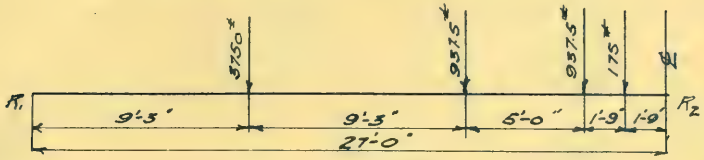
W = WEIGHT PER FOOT OF GIRDER

A = 12.5 (CONSTANT)

B = 200 (")



FLOOR BEAM COMPUTATIONS.



TOTAL L.L. DIAGRAM FOR 27'-0"

$$\text{CENTRE OF GRAVITY} = \frac{3750 \times 17.75 + 937.5 \times 12 + 175 \times 1.75}{5800} = 13.45'$$

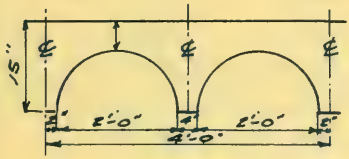
$$R = \frac{78052}{27} = 2890^{\#} \qquad M = 2890 \times 13.56 - 3750 \times 4.3 = 23{,}090 \text{ Ft}^{\#}$$

ASSUME FLOOR BEAMS 2'-0" ON ℄
THIS WILL INCREASE MOMENT BY
A MULTIPLE OF TWO.

$\therefore M_{LL.} = 2 \times 23090 = 46{,}180 \text{ Ft}^{\#}$

ASSUME CONCRETE AREA = 12"

CONCRETE WEIGHT PER LINEAL
FOOT = $1 \times 2 \times 0.832 \times 150 = 250^{\#}$



CONCRETE FILLING
BETWEEN FLOOR I
BEAMS

$$\text{MOMENT} = \frac{Wl^2}{8} \qquad W = 250^{\#} \quad l = 27'-0"$$

$$M = \frac{250 \times 27 \times 27}{8} = 27400 \text{ Ft}^{\#}$$

ASSUME IMPACT = 100% OF LIVE LOAD MOMENT

TOTAL MOMENT :-

L.L MOMENT = 46180

IMPACT = 46180

DEAD LOAD = 27400

119760 Ft$^{\#}$

A - 15" I BEAM @ 75$^{\#}$ WILL SATISFY.

S.C.A.

DESIGN OF SIDEWALK CANTILEVER

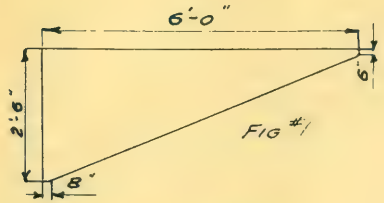


FIG #1

DESIGN OF WEB

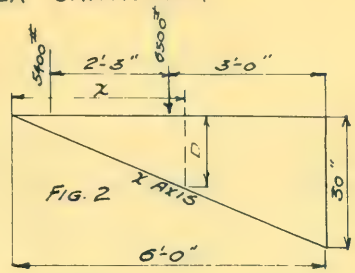


FIG. 2

LOADING DIAGRAM

SIDEWALK TO REST ON CANTILEVERS SPACED 6'-0" ON CENTRE. SIDEWALK 6'-0" WIDE.

MOMENT $= \frac{Wl}{2} + Pl'$ $W = 6300$ $l = 6'-0"$ $P = 5400$ $l' = 5'3"$

$M = \frac{6300 \times 6}{2} + 3400 \times 5.25 = 423$ KIP FT.

$M = \frac{SI}{C}$ $S = 16000$ $I = \frac{bd^2}{6}$ $b = X$ $d =$ AVERAGE DEPTH

$b = \frac{6 \times 423000 \times 12}{16000 \times 900} = 2.12"$ = TOTAL THICKNESS OF FLANGE

SHEAR $= 6300 + 5400 = 12700$ # AREA REQ'D $= \frac{12700}{10000} = 1.270"$

THICK OF WEB REQ'D $= \frac{1.27}{30} = 0.0423"$

USE WEB $\frac{3}{8}"$ THICK.

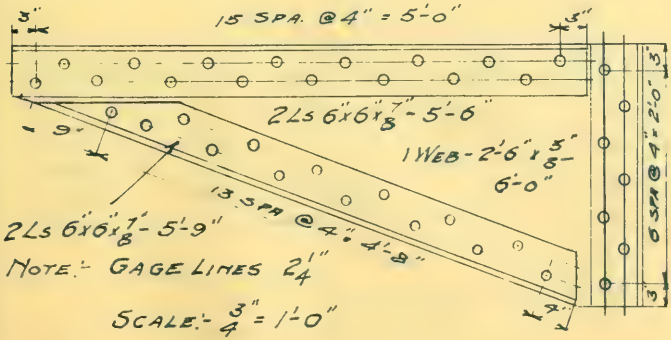
BENDING ALONG X-AXIS $= 452000$ FT #

STRESS $= \frac{452000 \times 12}{18} = 301,000$ #

AREA REQ'D $= \frac{301000}{16000} = 18.80"$

USE 2- 6"x6"x $\frac{7}{8}"$ ANGLES FOR FLANGES

CONNECTION ANGLES 2- 6"x6"x $\frac{7}{8}"$ RIVETS - 7 - FIELD



S.C.A.

STRESS SHEET FOR PLATE GIRDERS.

60'-0" CENTRAL GIRDER

NOTATION	L.L. TRACK	TR. IMPACT	L.L. UNIFORM	D.L. TRUSS	D.L. STREET	TOTAL
MOMENTS	1313.8	1120 0	723.0	857 0	3080.0	7093.8
END SHEAR	124.0	106.0	48 5	57.0	205.4	540 9
SHEAR $\frac{1}{4}$ PT	76 6	65.5	24.1	28.5	102.7	397.4
SHEAR $\frac{1}{2}$ PT	35.0	35.0	0	0	0	70.0

60'-0" SIDE GIRDERS

NOTATION	L.L. TRACK	TR IMPACT	L.L. UNIFORM	D.L. TRUSS	D.L. STREET AND SIDEWALK	TOTAL
MOMENTS	187.5	160.0	830.0	423.5	850	3986 0
END SHEAR	17.7	15.1	55.5	28.5	159.1	275. 9
SHEAR $\frac{1}{4}$ PT	10.9	10.9	27.7	14.25	79.5	143.5
SHEAR $\frac{1}{2}$ PT	5.1	5.1	0	0	0	10.2

52'-0" CENTRAL GIRDER

NOTATION	L.L TRACK	TR IMPACT	L.L. UNIFORM	D.L. TRUSS	D.L STREET	TOTAL
MOMENT	1034 0	825.0	544.0	368.0	2313	5284.0
END SHEAR	113.4	96.5	41.8	43.6	178 3	473 6
SHEAR $\frac{1}{4}$ PT	69.64	59.4	20 9	21.8	89.2	261.0
SHEAR $\frac{1}{2}$ PT	31.9	31.9	0	0	0	63.8

52'-0" SIDE GIRDERS

NOTATION	L.L. TRACK	TR IMPACT	L.L. UNIFORM	D.L. TRUSS	D.L. STREET AND SIDEWALK	TOTAL
MOMENTS	142.6	127.0	635.0	284.0	1890.5	2682.1
END SHEAR	16.2	13.8	46.0	21.8	144.1	241.9
SHEAR $\frac{1}{4}$ PT	9.93	8.46	23.0	10.9	72.0	123.73
SHEAR $\frac{1}{2}$ PT	4.55	4.55	0	0	0	9.10

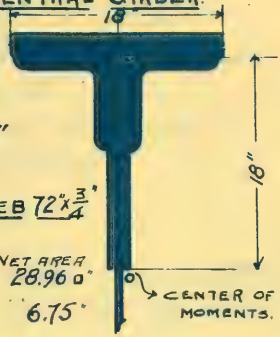
NOTE:-

BENDING MOMENTS ARE IN KIP-FEET.

SHEARS ARE IN KIPS.

S.C.A.

DESIGN OF 60'-0" CENTRAL GIRDER.



APPROXIMATE FLANGE STRESS
$= \frac{85000000}{72} = 1,180,000\#$

APPROXIMATE AREA $= \frac{1180,000}{16000} = 74 \square''$

WEB AREA $= \frac{540,400}{10,000} = 54 \square''$

" THICKNESS $= \frac{54}{72} = 0.75''$ USE WEB $72'' \times \frac{3}{4}''$

FLANGE SECTION

	GROSS AREA	NET AREA
2 ANGLES $8'' \times 8'' \times 1\frac{1}{8}''$	33.48 □"	28.96 □"
1/8 WEB AREA	6.75 "	6.75 "
2 PLATES $18'' \times \frac{1}{2}''$	18.00 "	16.00 "
2 COVER PLATES $18'' \times \frac{3}{4}''$	27.00 "	24.00 "
1 " " $18'' \times \frac{1}{2}''$	9.00 "	8.00 "
TOTAL	94.23 □"	83.71 □"

CENTER OF GRAVITY:- TOP COVER PLATE:- $9 \times 19.75 = 178.$

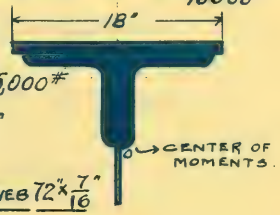
ANGLES:- $33.48 \times 15.59 = 522.$ 2nd " " :- $13.5 \times 19.125 = 259$

2 SIDE PLATES:- $18 \times 9 = 162.$ 3rd " " :- $13.5 \times 18.375 = 248.$

C. OF G. $= \frac{1369.25}{94.23} = 14.52''$ DIS. FROM ANGLE $= 18 - 14.52 = 3.48''$

EFFECTIVE DEPTH $= 72 - 2 \times 3.48 = 65.04.''$

ACTUAL STRESS $= \frac{85,000,000}{65.04} = 1,305,000\#$ ACTUAL AREA $= \frac{1305,000}{16000}$
$= 81.5 \square''$



60'-0" SIDE GIRDER.

APPROXIMATE STRESS $= \frac{47,800,000}{72} = 665,000\#$

" AREA $= \frac{665,000}{16,000} = 41.5 \square''$

WEB AREA $= \frac{275,900}{10000} = 27.6 \square''$

" THICKNESS $= \frac{27.6}{72} = 0.383''$ USE WEB $72'' \times \frac{7}{16}''$

FLANGE SECTION.

	GROSS AREA	NET AREA
2 ANGLES $8'' \times 8'' \times \frac{7}{8}''$	26.48 □"	22.96 □"
2 COVER PLATES $18'' \times \frac{1}{2}''$	18.00 "	16.00 "
1/8 WEB AREA	4.00 "	4.00 "
TOTAL	48.48 □"	42.96 □"

CENTER OF GRAVITY:- TOP COVER PLATE:- $9 \times 8.75 = 78.75$

ANGLES:- $26.48 \times 5.47 = 145.$ 2nd " " :- $9 \times 8.25 = 74.25$

C. OF G. $= \frac{298}{48.48} = 6.15''$ DIS. FROM ANGLE $= 8 - 6.15 = 1.85''$

EFFECTIVE DEPTH $= 72 - 2 \times 1.85 = 68.8.''$

ACTUAL STRESS $= \frac{47,800,000}{68.3} = 700,000\#$ ACTUAL AREA $= \frac{700,000}{16,000}$
$43.7 \square''$

STIFFENERS IN 60'-0" CENTRAL GIRDER.

END SHEAR TRANSMITTED TO ABUTMENT BY STIFFENERS.

$\frac{540,900}{14,420} = 38$ RIVETS; PLUS 50% = 57.

USE 19 RIVETS IN 3 PAIR OF STIFFENERS.

STRESS PER PAIR = $\frac{540,900}{3} = 180,300$ #

ASSUME ANGLES 6"x4"x1."

$S = 16,000 - \frac{70 \times 69.75}{0.86} = 10,325$ #

REQ'D. AREA ..... $= \frac{180300}{10325} = 17.5$ □" ACTUAL AREA = 18 □"

MINIMUM SIZE OF INTERMEDIATE STIFFENERS = $\frac{72}{30} + 2 = 4.4$"

USE ANGLES 5"x3$\frac{1}{2}$"x$\frac{3}{4}$".

SPACING OF STIFFENERS.

$d = \frac{t}{40}(12000 - S)$ ..... { d = spacing. t = WEB THICKNESS. S = STRESS PER □"

END SPACING = $d = \frac{3}{160}\left(12000 - \frac{540,900}{54}\right) = 38"$

INTERMEDIATE SPACING

$= d = \frac{3}{160}\left(12000 - \frac{397400}{54}\right) = 87"$

SPACING NOT TO EXCEED 6'-0".

STIFFENERS IN 60'-0" SIDE GIRDER.

REQ'D. RIVETS = $\frac{275,900}{9188} = 30$; PLUS 50% = 45.

USE 15 RIVETS IN 3 PAIR OF STIFFENERS.

STRESS PER PAIR = $\frac{275,900}{3} = 91,934$ #

ASSUME ANGLES 6"x4"x$\frac{1}{2}$"

$S = 16,000 - \frac{70 \times 69.75}{0.87} = 10,385$ #

REQ'D. AREA = $\frac{91,934}{10,385} = 8.85$ □" ACTUAL AREA = 9.5 □".

MINIMUM SIZE OF INTERMEDIATE STIFFENERS = $\frac{72}{30} + 2 = 4.4$'

USE ANGLES 5"x3$\frac{1}{2}$"x$\frac{1}{2}$"

SPACING OF STIFFENERS.

$d = \frac{t}{40}(12,000 - S)$ (SEE ABOVE)

END SPACING = $d = \frac{7}{640}\left(12,000 - \frac{275,900}{31.5}\right) = 22"$

INTERMEDIATE SPACING = $d = \frac{7}{640}\left(12000 - \frac{143,500}{31.5}\right) = 82"$

VEB.

WEB SPLICE FOR 60'-0" CENTRAL GIRDER.

SPLICE TO OCCURE AT OR NEAR THE 1/3 POINT. MOMENT RESISTED BY WEB = $\frac{6.75 \times 85,000,000}{54} = 10,630,000$

$0.75 \times 10,630,000 = 7,972,500$# TAKEN BY STRAPS. ASSUME 30 RIVETS.

STRESS PER RIVET, $S = \frac{26 \cdot 7972500}{10(20^2+23^2+26^2)} = 12,900$# ALLOWED = 14,432#

4 STRAP PLATES $30" \times 10" \times \frac{1}{2}"$

$.025 \cdot 10,630,000 = 2,657,500$"# TAKEN BY VERTICAL PLATE. ASSUME 36 RIVETS

$S = \frac{16.5 \cdot 2,657,500}{6(16.5^2+13.5^2+10.5^2+7.5^2+4.5^2+1.5^2)} = 11,360$#

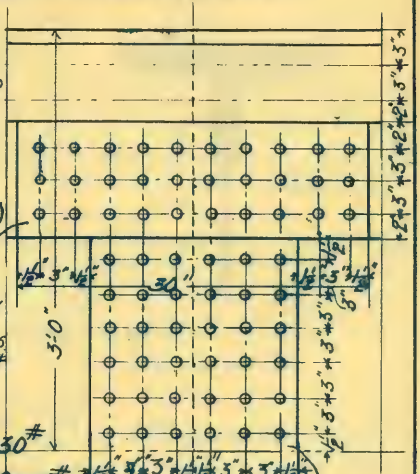
STRESS DUE TO SHEAR = $\frac{397,400}{72} = 5525$#. RESULT = $\sqrt{(11360^2+5525^2)} = 12,630$#

STRESS AT OUTER FIBRE = $\frac{18 \times 16000}{36} = 8000$#

I_p (PLATES) = $2 \times \frac{1125 \times 36^3}{12} = 8750$ I_R(RIVETS) = $4\{6 \cdot 1.125 + 1.125(643.5) = 2601$

$I = I_p - I_R = 2343$. $S = \frac{Mc}{I} = \frac{2,657,500}{6149} \times 18 = 7800$#

USE 2 VERTICAL SPLICE PLATES $36" \times 18" \times 1\frac{1}{4}"$



WEB SPLICE FOR 60'-0" SIDE GIRDER.

MOMENT RESISTED BY WEB = $\frac{47,800,000}{27.6} \times 3.85 = 6,675,000$"#

ASSUME PLATE ON 7/8" FILLERS AND 132 RIVETS. STRESS PER RIVET

$S = \frac{33 \times 6,675,000}{6(33^2+30^2+25.5^2+16.5^2+13.5^2+10.5^2 \ldots 1.5^2)}$

$= 8000$# ALLOWED = 9188#

TOTAL RIVETS = 132 + 50% = 198.

USE 2 PLATES $70\frac{1}{4}" \times 18 \times \frac{1}{2}"$

" 2 FILLERS $36 \times 30" \times \frac{7}{8}"$

STRESS DUE TO SHEAR = $\frac{143,500}{132} = 1090$#. RESULT = $\sqrt{(8000^2+1090^2)} = 8100$#

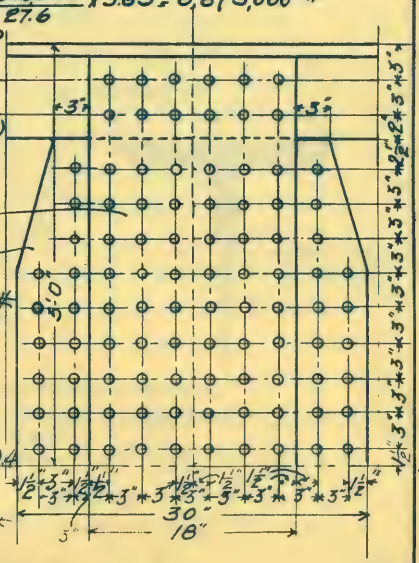
STRESS AT OUTER FIBRE = $\frac{35.125}{36} \times 16000 = 15,700$#

$I_p = 2 \cdot \frac{0.5 \times 70.25^3}{12} = 28,000.$

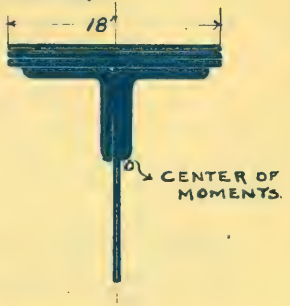
$I_R = 4\{(11 \times 0.042) + 0.5(4169.5) = 8340.4$

$I = I_p - I_R = 20559.6.$

$S = \frac{6675000 \times 35.125}{20559.6} = 11,450$#



DESIGN OF 52'-0" CENTRAL GIRDER



MOMENT = 5,28,400 x 12 = 63,400,000"#

STRESS = $\frac{63400000}{72}$ = 880,000#

AREA REQ'D = $\frac{880000}{16000}$ = 55 □"

FOR FLANGES

SECTION:- EFFECTIVE

2 COVER PLATES 18" x $\frac{1}{2}$"

1 COVER PLATE 18 x $\frac{3}{4}$"

$\frac{1}{8}$ WEB AREA

2 LS 8" x 8" x 1" GROSS AREA = 67.7 □"

NET AREA = 60.2 □"

CENTRE OF GRAVITY OF SECTION = $\frac{9 \times 9.5 + 9 \times 9 + 13.6 \times 8.375 + 30 \times 5.63}{67.7} = \frac{448.6}{67.7} = 6.62$"

8 - 6.62 = 1.38" FROM TOP OF ANGLE

EFFECTIVE DEPTH = 72" - 2.7" = 69.34"

ACTUAL STRESS = $\frac{63400000}{69.34}$ = 916000#

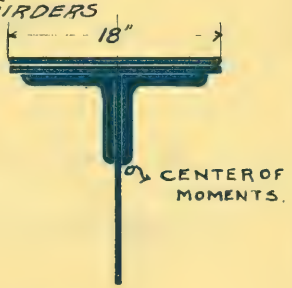
ACTUAL AREA NEEDED = $\frac{916000}{16000}$ = 57.2 □"

∴ SECTION SAFE

WEB SECTION:- SHEAR = 473000# AREA REQ'D = $\frac{473000}{10000}$ = 47.4 □" $\frac{47.4}{72}$ = 0.67"

USE WEB 72" x $\frac{11}{16}$"

DESIGN OF 52'-0" SIDE GIRDERS



MOMENT = 2,682,100 1# = 32,200,000"#

STRESS = $\frac{32200000}{72}$ = 447500#

AREA REQ'D = $\frac{447500}{16000}$ = 27.95 □"

SECTION:- EFFECTIVE

2 COVER PLATES 18" x $\frac{1}{2}$"

$\frac{1}{8}$ WEB = 3.4"

2 LS 8" x 8" x $\frac{3}{4}$"

GROSS AREA = 44.28 □" NET AREA = 39.28 □"

CENTRE OF GRAVITY = $\frac{9 \times 8.75 + 9 \times 8.25 + 22.88 \times 5.72}{44.28} = 8.67$"

EFFECTIVE DEPTH = 73.24" STRESS = $\frac{32200000}{73.34} = 440000$#

ACTUAL AREA $\frac{440000}{16000}$ = 28.5" SECTION SAFE

WEB SECTION:- SHEAR = 241900# AREA REQ'D $\frac{241900}{10000} = 24.2$"

USE $\frac{24.2}{72} = 0.336$" WEB SECTION 72" x $\frac{5}{8}$"

I.B.
S.C.A.

STIFFENERS IN 52'-0" CENTRAL GIRDER.

REQ'D. RIVETS = $\frac{473,600}{14,432}$ = 34, PLUS 50% = 51.

USE 17 RIVETS IN 3 PAIR OF STIFFENERS.

STRESS PER PAIR = $\frac{473,600}{3}$ = 15,7867#

ASSUME ANGLES 6"x4"x$\frac{7}{8}$".

$S = 16,000 - \frac{70 \times 69.75}{0.86} = 10,325$#

REQ'D. AREA = $\frac{157,867}{10325}$ = 15.780" ACTUAL AREA = 17.880"

MINIMUM SIZE OF INTERMEDIATE STIFFENERS = $\frac{72}{30} + 2 = 4.4$"

USE ANGLES 5"x3$\frac{1}{2}$"x$\frac{3}{4}$".

SPACING OF STIFFENERS.

$d = \frac{t}{40}(12,000 - S)$

END SPACING = $d = \frac{11}{640}(12000 - \frac{473600}{49.5}) = 35$"

INTERMDIATE SPACING.

$d = \frac{11}{640}(12000 - \frac{261,000}{49.5}) = 115.5$"

SPACING NOT TO EXCEED 6'-0"

STIFFENERS IN 52'-0" SIDE GIRDER.

REQ'D. RIVETS = $\frac{241,900}{7876}$ = 32, PLUS 50% = 48.

USE 16 RIVETS IN 3 PAIR OF STIFFENERS.

STRESS PER PAIR = $\frac{241,900}{3}$ = 80,634#

ASSUME ANGLES 6"x4"x$\frac{1}{2}$".

$S = 16,000 - \frac{70 \times 69.75}{0.87} = 10,385$#

REQ'D. AREA = $\frac{80634}{10385}$ = 7.750" ACTUAL AREA = 9.50"

MINIMUM SIZE OF INTERMEDIATE STIEEENERS = $\frac{72}{30} + 2 = 4.4$"

USE ANGLES 5"x3$\frac{1}{2}$"x$\frac{3}{8}$".

SPACING OF STIFFENERS.

$d = \frac{t}{40}(12,000 - S)$.

END SPACING = $\frac{3}{320}(12,000 - \frac{241,900}{27}) = 19$."

INTERMEDIATE SPACING = $d = \frac{3}{320}(12,000 - \frac{123,730}{27}) = 70$"

DESIGN OF SPLICE PLATES FOR 52'-0" - CENTRAL AND SIDE GIRDERS.

CENTRAL GIRDER

MAX. SHEAR AT $\frac{1}{2}$ PT = 31900 #

MAX BENDING = 63,400,000 "#

BEND. MOM TAKEN BY $\frac{1}{8}$ WEB =

$\frac{\frac{1}{8}\text{WEB} \times 63400000}{\text{FLANGE AREA}} = \frac{6.2 \times 63400000}{60.2}$

= 6,550,000 "# TRY 2-$\frac{3}{4}$" PLATES

$M = \frac{SI}{C}$ S = X I = CALCULATE C = 28"

$I = \frac{.75 \times 56^3}{12} = 2\left(\frac{1}{2} \times 1 \times 9\,(4+9+16+25+36+49+64+81)\right)$

= 11000 - 2556 = 8444.

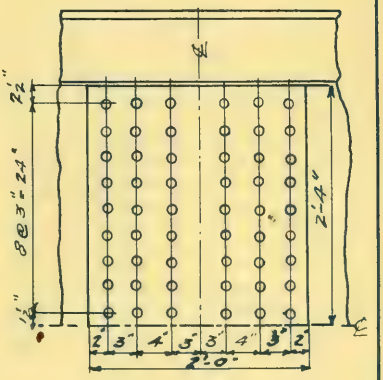
$\frac{2SI}{C} = 6550000$ $S = \frac{6550000 \times 28}{8444 \times 2}$

S = 11000 # SAFE AS MAX STRESS

ALLOWED AT THIS POINT = 14200 #

2 SPLICE PLATES 56" x $\frac{3}{4}$ O.K.

FOR SHEAR STRESSES.



DESIGN FOR RIVET STRESSES.

S_R = NO. RIVETS x STRESS IN EACH RIVET

$S_R = 6 \times \frac{3}{9} \times F\,(81+64+49+36+25+16+9+4+1) = 6 \times \frac{1}{3} \times F \times 258$

$F = (14432^2 + 880^2)^{\frac{1}{2}} = 14521$

$\therefore S = \frac{6 \times 3 \times 14521 \times 258}{9} = 7{,}500{,}000$ "# AS STRESS RIVETS WILL CARRY. LOAD ON RIVETS = 6,500,000 "#

$\therefore$ NO. RIVETS SAFE

SIDE GIRDERS.

MAX. SHEAR AT $\frac{1}{2}$ PT = 31900 #

MAX BENDING = 32,200,000 "#

BENDING TAKEN BY $\frac{1}{8}$ WEB AS ABOVE

$\frac{32200000 \times 3.4}{3228} = 2{,}780{,}000$ "#

I = BY SAME METHOD AS ABOVE = 4763

$S = \frac{2780000 \times 28}{4763 \times 2} = 8000$ #

SECTION SAFE 2-PLATES 56" x $\frac{1}{2}$"

RIVET STRESSES.-

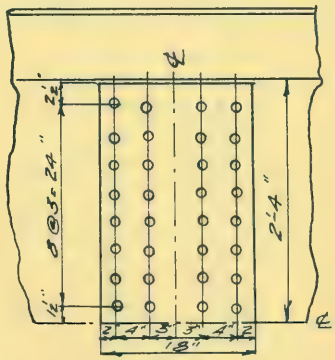
$S_R = 4 \times \frac{3}{9} \times F\,(81+64+49+36+25+16+9+4+1)$

$S_R = 4 \times \frac{1}{3} \times F \times 258$ F = 14521.

$S_R = \frac{4 \times 1 \times 14521 \times 258}{3} = 5{,}200{,}000$ #

ACTUAL LOAD = 2,780,000 "#

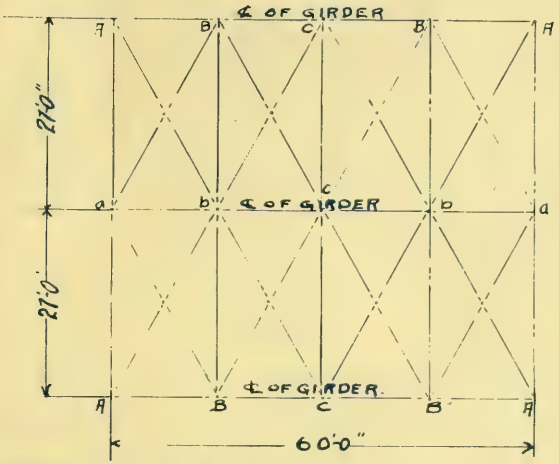
$\therefore$ NO RIVETS SAFE



SCALE $\frac{3}{4}$" = 1'-0"

S.C.A.

LATERAL BRACING FOR 60'-0" GIRDER.



$\varphi = 29°-4'$ Sec. $\varphi = 1.144$

HEAVIEST LOAD FOLLOWING C.B.L. = $48000 \div 10 = 4800^{\#}$

LOADING PER FOOT = $200 + 200 + 480 = 880^{\#}$ $880 \times 15 = 13300^{\#}$

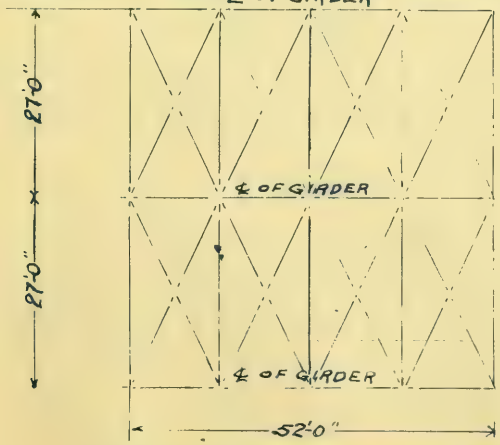
LENGTH OF DIAGONALS = $\sqrt{(\overline{27}^2 + \overline{15}^2)} = 34.875' = 34'-10\frac{1}{2}"$

STRESS IN Ab = $\frac{W}{4}(1+2+3) \times \text{Sec.}\varphi = \frac{13300}{4} \times 6 \times 1.14 = 22400^{\#}$

" " Bc = $\frac{W}{4}(1+2) \times \text{Sec.}\varphi = \frac{13300}{4} \times 3 \times 1.14 = 11800^{\#}$

REQ'd. AREA = $\frac{22400}{16000} = 1.4^{\square"}$. Use 2 ANGLES $3\frac{1}{2}" \times 3" \times \frac{3}{8}"$.

" RIVETS = $\frac{22400}{7210} = 4$ USE SAME ANGLES FOR 52'-0"

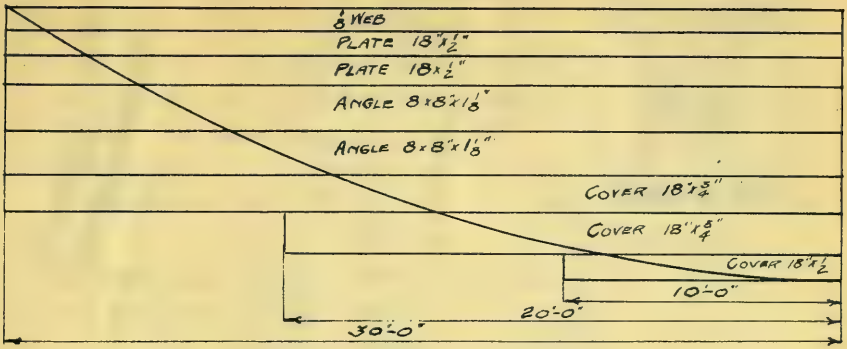


LATERAL BRACING FOR 52'-0" GIRDER

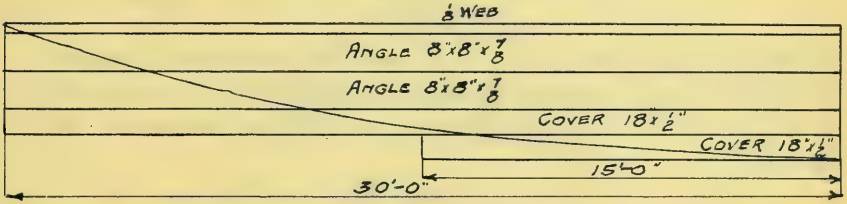
WEB

LENGTH OF COVER PLATES

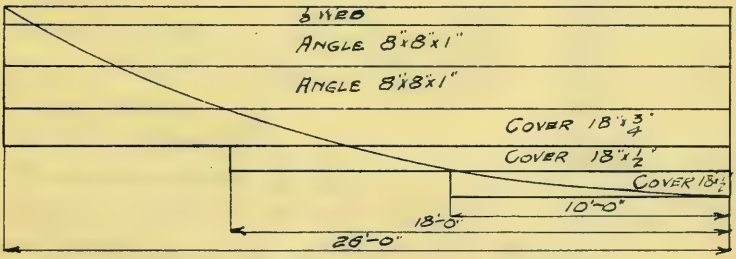
60'-0" CENTRAL GIRDER



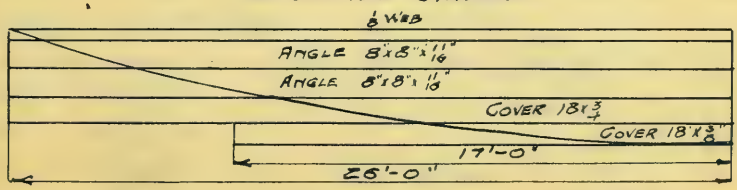
60'-0" SIDE GIRDER



52'-0" CENTRAL GIRDER



52'-0" SIDE GIRDER

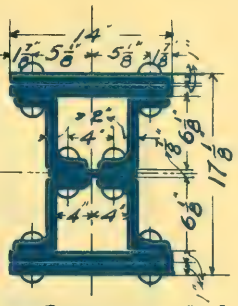


SCALE
1" = 1'-0"

COLUMNS FOR CENTRAL GIRDERS.

THE GREATEST REACTION OCCURES AT THE JUNCTION OF THE 60'-0" AND 52'-0" GIRDERS; AND = 540,900 + 473,600 = 1,014,500#

LEAST RADIUS OF GYRATION OCCURES ABOUT THE VERTICAL AXIS = $R = \sqrt{\frac{I}{A}}$



SECTION:-	$I = \Sigma I_1 + I_2$.		AREA
1 COVER PLATE 14"x1"	229	0	14 □"
1 " " 14"x1"	229	0	14 □"
2-Z-BARS $6\frac{1}{8}"x3\frac{5}{8}"x\frac{7}{8}"$	38.36	257.5	20.34
1 WEB PLATE $7\frac{3}{4}"x\frac{1}{8}"$	34.0	0	6.78
HALF TOTAL	787.86		55.12 □"

$R = \sqrt{\frac{787.86}{55.12}} = 3.79.$ $P = \frac{50,000}{1 + \frac{(12 \cdot 20.5)^2}{36,000 \times (3.79)^2}} = 47,300\#$

USING A SAFETY FACTOR OF 4, UNIT STRESS S = 11,825#

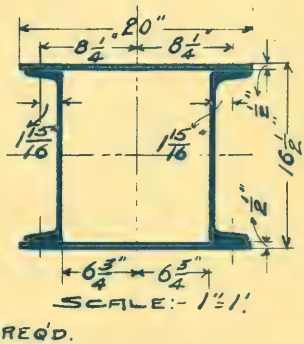
REQ'D. AREA = $\frac{1,014,500}{11825} = 85.6$ □" ACTUAL AREA = 110.24 □"

10 OF THESE COLUMNS ARE REQ'D.

COLUMNS FOR SIDE GIRDERS.

TOTAL LOAD = 275,900 + 241,900 = 517,800#

A STANDARD PLATE AND CHANNEL COLUMN OF THE FOLLOWING SECTION IS NECESSARY.



2-35# CHANNELS.

2- COVER PLATES $20"x\frac{1}{2}"$.

SIZE OF TOP AND BOTTOM PLATES ON THESE COLUMNS; $22\frac{1}{2}"x20"x1"$. 40 REQ'D.

SIZE OF SAID PLATES ON CENTRAL COLUMNS ARE; $17\frac{1}{8}"x16"x1"$. 20 REQ'D.

CONNECTION ANGLES FOR BOTH SETS; $6"x4"x\frac{1}{2}"$, X.

40- $6"x4"x\frac{1}{2}"x14"$ USED ON CENTRAL SET.

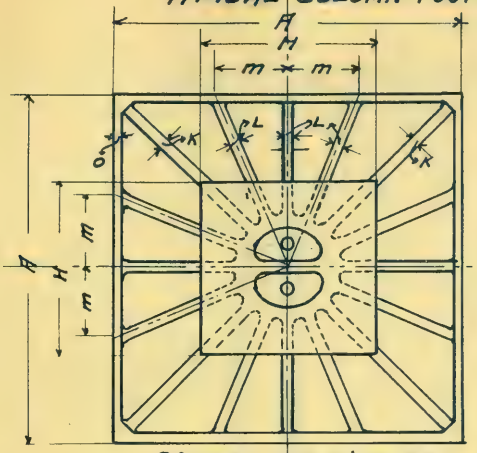
40- $6"x4"x\frac{1}{2}"x10"$ " " " "

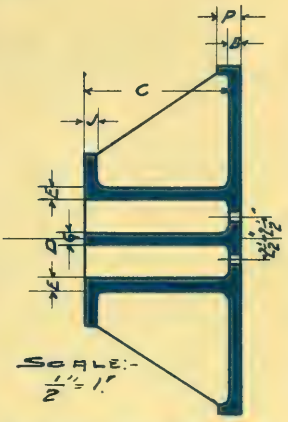
80- $6"x4"x\frac{1}{2}"x20"$ " " SIDE "

80- $6"x4"x\frac{1}{2}"x12"$ " " " "

VRB.

TYPICAL COLUMN FOOTINGS.

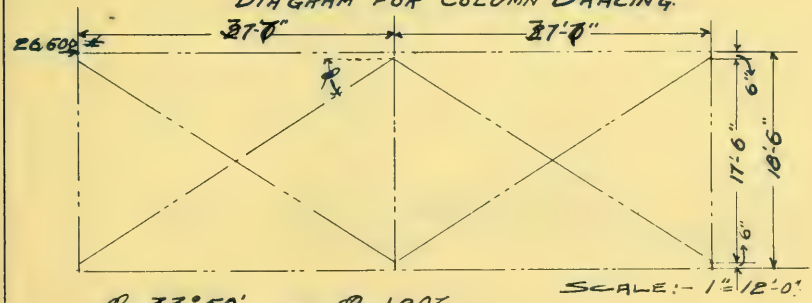




20 REQ'D. FOR SIDE SET. 10 REQ'D. FOR CEN. SET.

USED UNDER	BASE PLATE A	BASE PLATE B	HEIGHT C	HUB DIAM. D	HUB THICK. E	HUB RIB G	CAP PLATE H	CAP PLATE J	RIBS COR. K.	RIBS INT. L.	RIBS DIST. m	RIBS O	RIBS P	WEIGHT OF FOOTING	ALLOWED BEARING
CEN. GIRD.	5'	2'-1"	2'-3"	13"	2-¼"	2"	2'-5"	2"	2"	1-¾"	1'-0½"	1½"	4½"	6,550#	1.250 k.
SIDE GIRD.	5'	2"	2'-3"	13"	2"	1¾"	2'-5"	1¾"	1¾"	½"	1'-0½"	½"	4"	5850#	1.000 k.

DIAGRAM FOR COLUMN BRACING.



$\phi = 33°50'$. SEC. $\phi = 1.203$.

STRESS IN DIAGONAL = $26600 \times \text{SEC}\,\phi = 32{,}000\#$

REQ'D. AREA = $\frac{32{,}000}{16000} = 2$ □"

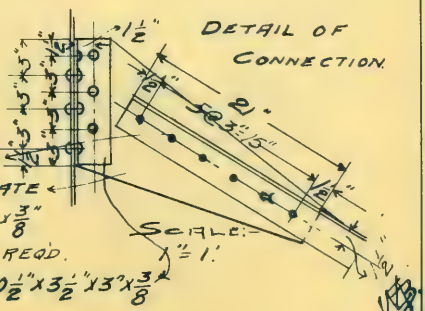
USE 1 ANGLE $3\frac{1}{2}" \times 3" \times \frac{3}{8}"$ - 40 REQ'D.

USE $\frac{7}{8}"$ RIVETS. GUSSET PLATE

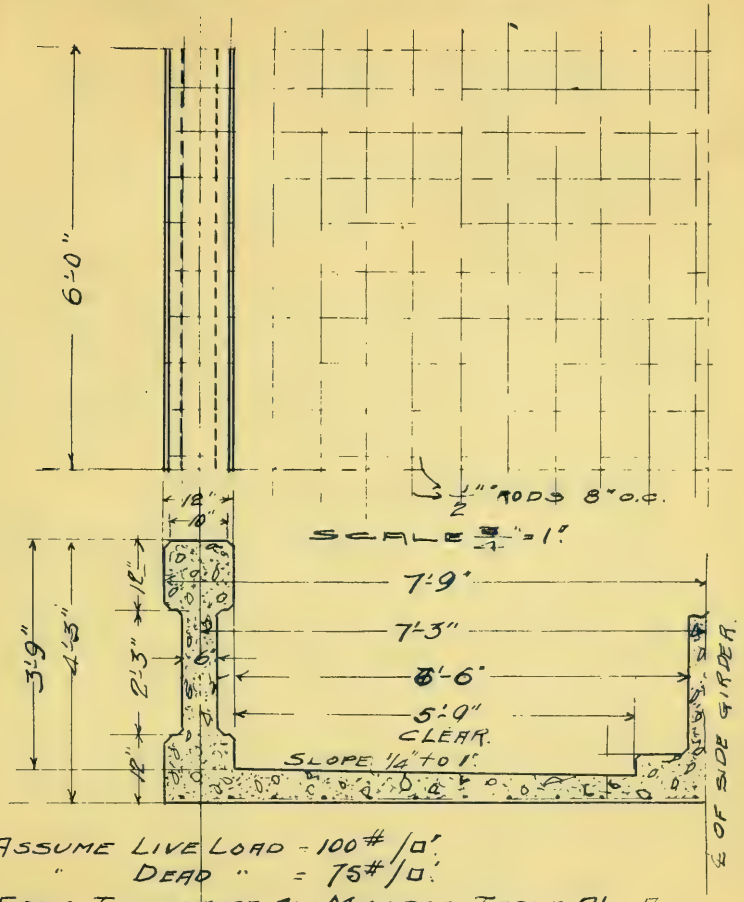
REQ'D. NO. = $\frac{32000}{6013} = 6$. $1'-7\frac{1}{2}" \times 1'-5\frac{1}{2}" \times \frac{3}{8}"$

SHOP CONNECTION; USE 3. 240 REQ'D.

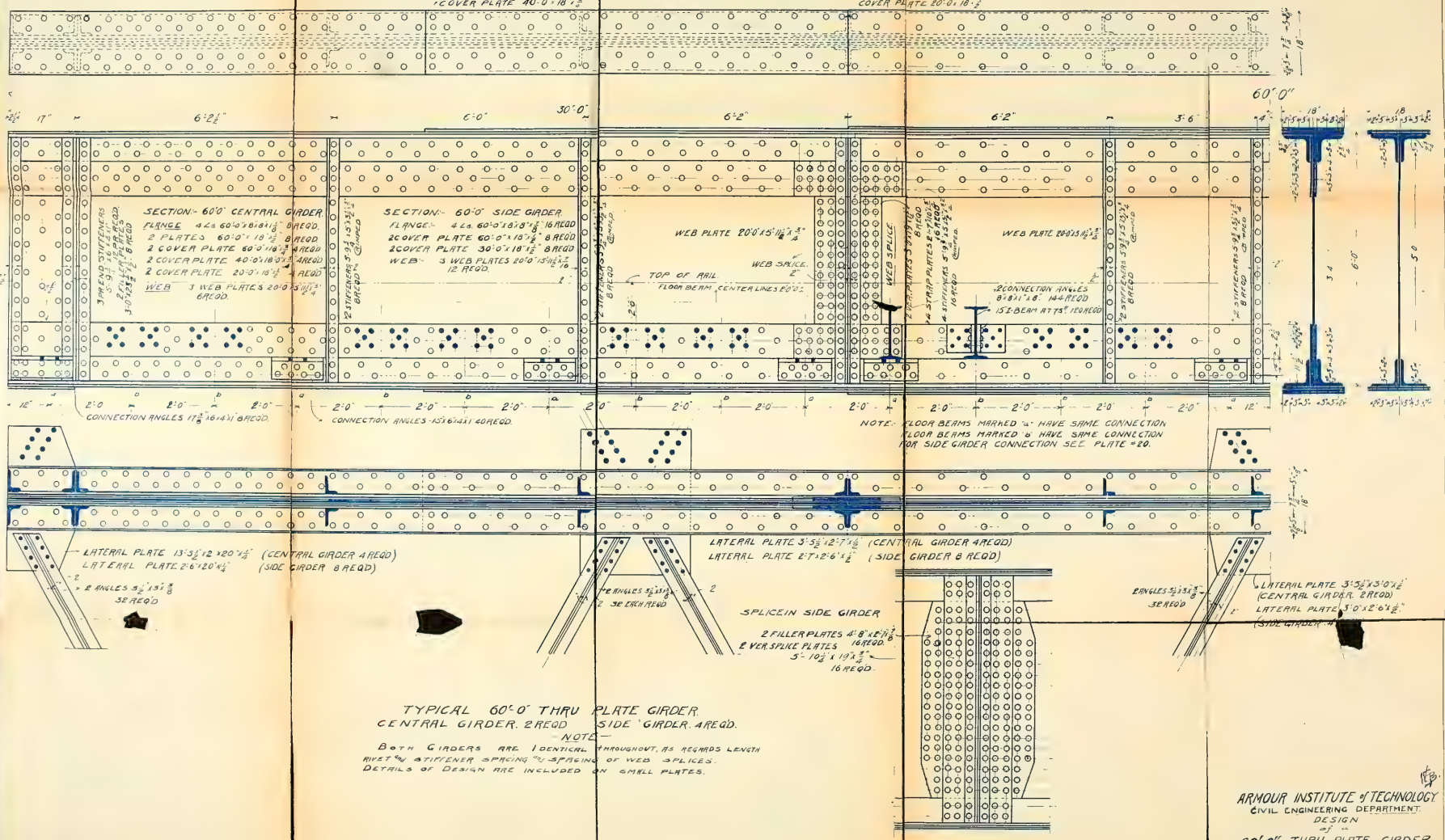
480 CONNECTION ANGLES REQ'D. $10\frac{1}{2}" \times 3\frac{1}{2}" \times 3" \times \frac{3}{8}"$


1½"
3"
3"
3

DESIGN OF CONCRETE SIDEWALK.



ASSUME LIVE LOAD = 100#/□'
" DEAD " = 75#/□'
FROM TURNEAURE and MAURER, TABLE 21 A
5" SLAB WILL BE NECESSARY.
REINFORCEMENT CONSISTS OF 1/2" RODS 8" O.C.
USED BOTH WAYS. THE SLAB IS HUNG ON
STEEL CANTILEVERS 6'-0" O.C.


COVER PLATE 40'-0" x 18"-1 3/8
COVER PLATE 20'-0" x 18"-1/2
60'-0"
30'-0"
SECTION:- 60'-0" CENTRAL GIRDER.
FLANGE 4 Le. 6"-0" x 6" x 13/16" 8 REQD.
2 PLATES 60'-0" x 18"-1/2" 8 REQD.
2 COVER PLATE 60'-0" x 18"-3/8" 8 REQD.
2 COVER PLATE 40'-0" x 18"-1 3/8" 4 REQD.
2 COVER PLATE 20'-0" x 18"-1/2" 4 REQD.
WEB 3 WEB PLATES 20'-0" x 15"-11/16" x 7/16 6 REQD.
SECTION:- 60'-0" SIDE GIRDER.
FLANGE:- 4 Le. 6"-0" x 6" x 13/16" 16 REQD
2 COVER PLATE 60'-0" x 18"-1/2" 8 REQD
2 COVER PLATE 30'-0" x 18"-1/2" 8 REQD
WEB:- 3 WEB PLATES 20'-0" x 15"-11/16" x 7/16 12 REQD.
WEB PLATE 20'-0" x 15"-11/16" x 3/8
WEB PLATE 20'-0" x 15"-11/16" x 7/16
WEB SPLICE.
TOP OF RAIL.
FLOOR BEAM CENTER LINES EQ'D.
2 CONNECTION ANGLES 6" x 6" x 13/16" x 6" 14 REQD
15 I. BEAM AT 73 LBS 10 REQD
CONNECTION ANGLES 17 3/8" x 6" x 13/16" x 4 1/2" 8 REQD.
CONNECTION ANGLES - 15" x 6" x 13/16" x 4 1/2" 4 REQD.
NOTE:- FLOOR BEAMS MARKED "a" HAVE SAME CONNECTION
FLOOR BEAMS MARKED "b" HAVE SAME CONNECTION
FOR SIDE GIRDER CONNECTION SEE PLATE #20.
LATERAL PLATE 13'-5 1/2" x 12" x 20" x 1/4" (CENTRAL GIRDER 4 REQD)
LATERAL PLATE 2'-6" x 20" x 1/4" (SIDE GIRDER 8 REQD)
2 ANGLES 5 1/2" x 3 1/2" x 7/8" 32 REQ'D
2 ANGLES 5 1/2" x 3 1/2" x 7/8" 2 32 EACH REQD
LATERAL PLATE 3'-5 1/2" x 12'-7 1/2" (CENTRAL GIRDER 4 REQD)
LATERAL PLATE 2'-7" x 2'-6" x 1/2" (SIDE GIRDER 8 REQD)
SPLICE IN SIDE GIRDER
2 FILLER PLATES 4'-8" x 12" x 7/8" 16 REQD.
2 VER. SPLICE PLATES 5'-10 1/2" x 19" x 5/8" 16 REQD.
2 ANGLES 5 1/2" x 3 1/2" x 7/8" 32 REQD
LATERAL PLATE 3'-5 1/2" x 3'-0" x 1/2" (CENTRAL GIRDER 2 REQD)
LATERAL PLATE 3'-0" x 2'-6" x 1/2" (SIDE GIRDER 4)

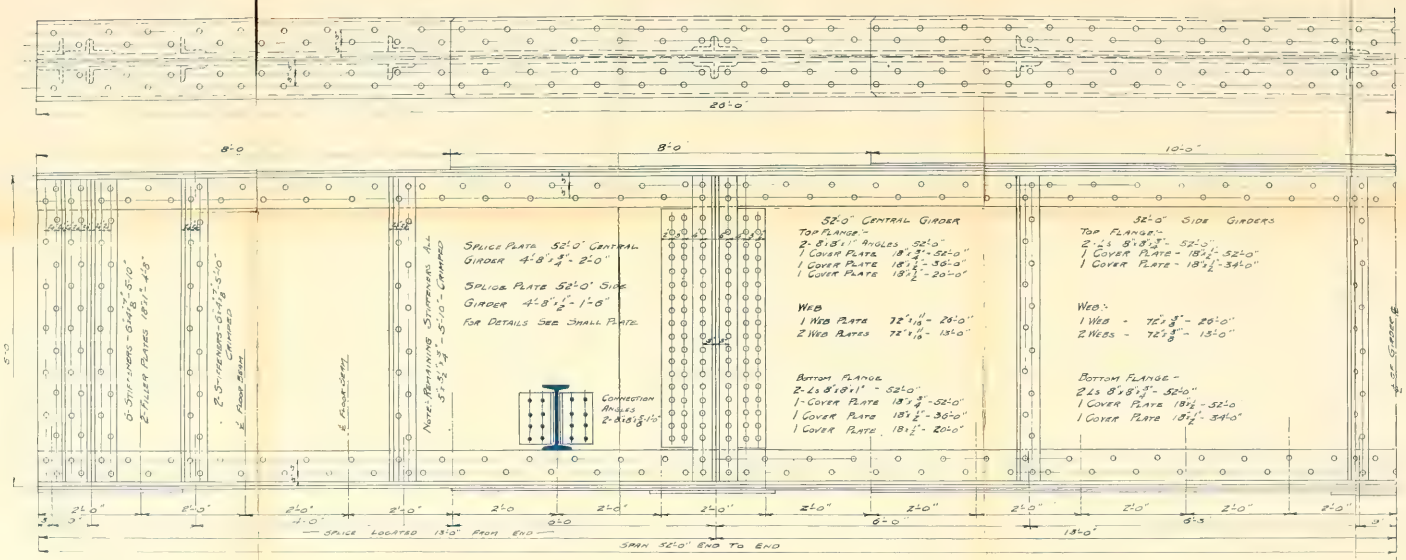
TYPICAL 60'-0" THRU PLATE GIRDER

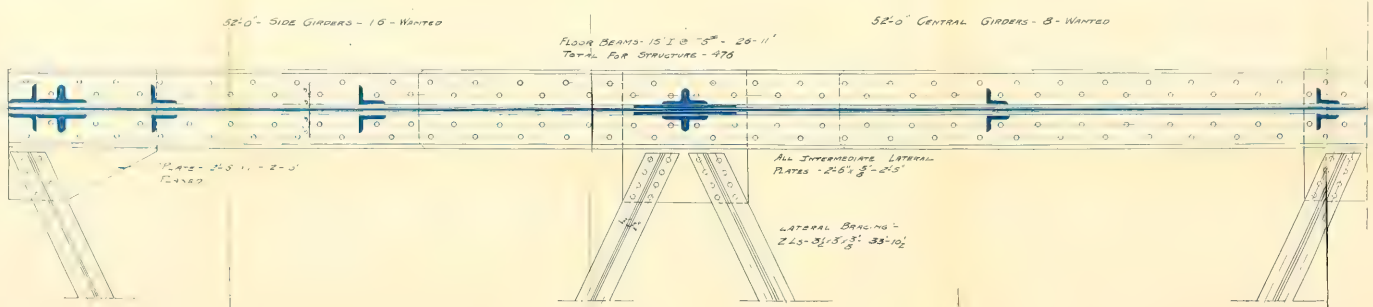
CENTRAL GIRDER. 2 REQD. SIDE GIRDER. 4 REQ'D.

— NOTE —

BOTH GIRDERS ARE IDENTICAL THROUGHOUT, AS REGARDS LENGTH RIVET & STIFFENER SPACING & SPACING OF WEB SPLICES. DETAILS OF DESIGN ARE INCLUDED ON SMALL PLATES.

ARMOUR INSTITUTE of TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT.
DESIGN
of a
60'-0" THRU PLATE GIRDER
FOR THE
MILWAUKEE AVENUE VIADUCT.
Scale 1"=1'
May 23, 1912
William Beach


26'-0"
8'-0
8'-0
10'-0"
5'-0
6 Stiffeners - 0'-4 7/8" x 5'-0"
2 Filler Plates 18" x 4'-8"
2 Stiffeners - 0'-7" x 3'-10" Chamfered
4" Floor Beam
4" Floor Girder
Note: Remaining Stiffeners All 3" x 3" x 1/4" x 5'-0" - Chamfered
Splice Plate 52'-0" Central Girder 4'-8 1/2" x 2'-0"
Splice Plate 52'-0" Side Girder 4'-8 1/2" x 1'-6"
For Details See Small Plate.
Connection Angles 2-8 x 8 x 5/16 x 1'-0"
52'-0" Central Girder
Top Flange -
2-8"x8"x1" Angles 52'-0"
1 Cover Plate 18" x 3/4" - 52'-0"
1 Cover Plate 18" x 1/2" - 36'-0"
1 Cover Plate 18" x 1/2" - 20'-0"
Web
1 Web Plate 72" x 11/16" - 28'-0"
2 Web Plates 72" x 1/2" - 13'-0"
Bottom Flange -
2 Ls 8" x 8" x 1" - 52'-0"
1 Cover Plate 18" x 3/4" - 52'-0"
1 Cover Plate 18" x 1/2" - 36'-0"
1 Cover Plate 18" x 1/2" - 20'-0"
52'-0" Side Girders
Top Flange -
2 Ls 8" x 8" x 1" - 52'-0"
1 Cover Plate - 18" x 1/2" - 52'-0"
1 Cover Plate - 18" x 1/2" - 34'-0"
Web -
1 Web - 72" x 3/8" - 28'-0"
2 Webs - 72" x 3/8" - 13'-0"
Bottom Flange -
2 Ls 8" x 8" x 1" - 52'-0"
1 Cover Plate 18" x 1/2" - 52'-0
1 Cover Plate 18" x 1/2" - 34'-0"
2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0"
3" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 3"
Splice Located 13'-0" from End
6'-0"
13'-0"
8'-3
Span 52'-0" End to End
1'-6"
1'-6"
Cross Section of Central Girders
Side

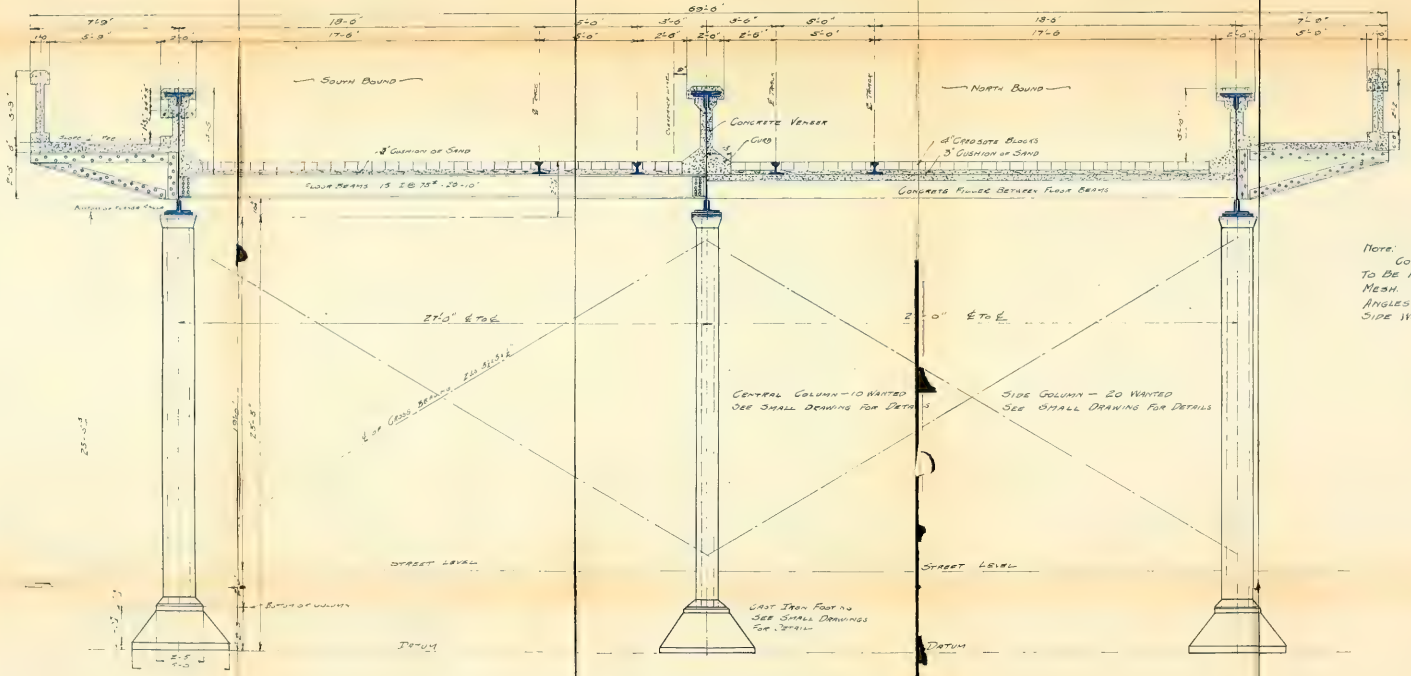

52'-0" - Side Girders - 16 - Wanted
52'-0" Central Girders - 8 - Wanted
Floor Beams - 15 I @ 5# - 26' 11"
Total For Structure - 476
Plate - 2'-5 1/2" - 2'-3" Flared
All Intermediate Lateral Plates - 2'-6" x 5/8" - 2'-5"
Lateral Bracing -
2 Ls - 3 1/2" x 3 1/2" x 5/8" - 33'-10 1/2"

Design Of A Typical 52'-0" Girder

Note:- The Central And Side Girders Image Identical Design Varying Only In Sections As Noted. Rivet Spacing - Laterals - Stiffeners Are Made The Same. Variations In Section Noted For Detail Design See Small Plate Accompaning

ARMOUR INSTITUTE OF TECHNOLOGY
Civil Engineering Department
The Reconstruction of the Milwaukee Ave. Viaduct. — Chicago Ill.
Design of a Typical 52'-0" Thru' Girder
Scale 1"=1'-0" Drawn By- S.C. Anderson

Typical Cross Section of Viaduct

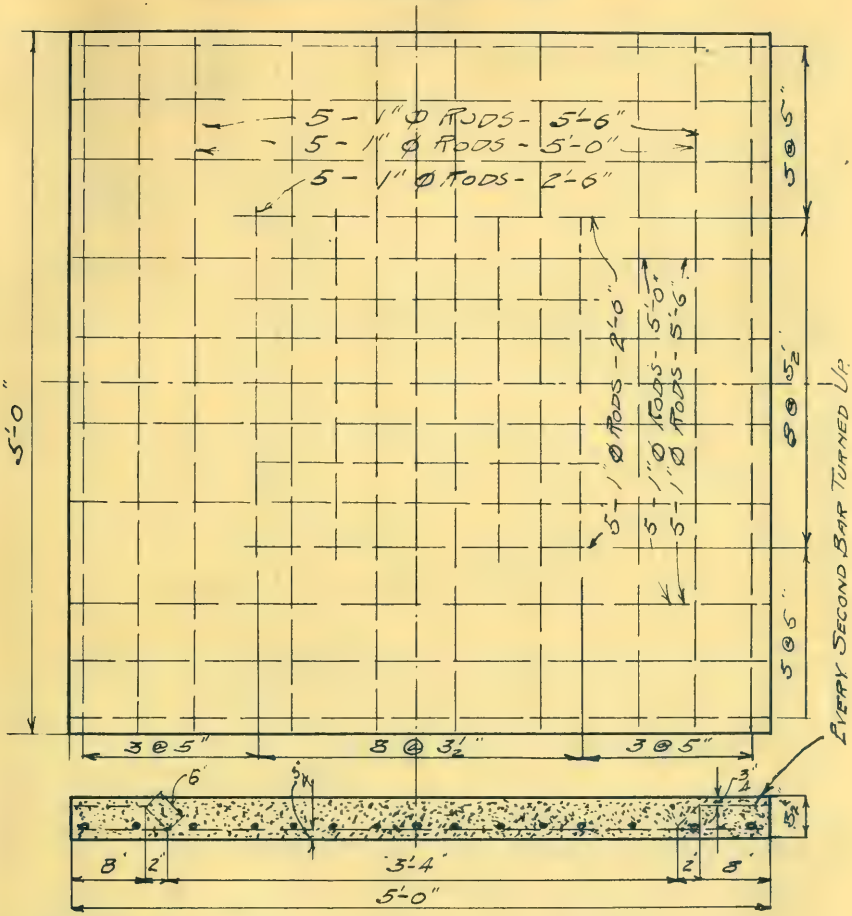


Note:
Concrete Veneering on Plate Girders To be Hung to Flanges and Webs by Wire Mesh. Curb to be Supported by 4"x4"x⅜" Angles Between Cantilever Sidewalk Spans. Side Walk Cantilevers 10'-0" on Center-line

This Drawing Gives General Dimensions Only For A More Complete Design Of Parts See Small Drawings

ARMOUR INSTITUTE OF TECHNOLOGY
Civil Engineering Department
The Reconstruction of the Milwaukee Ave. Viaduct. — Chicago. Ill.
Typical Cross Section of Viaduct
Scale ⅜" = 1'-0" Drawn By: S. Anderson '12

DESIGN OF SLABS FOR CONCRETE.
SECTION NORTH END.



GIRDERS AND BEAMS 5'-0" ON ℄s ∴ SLAB = 5'-0" x 5'-0"

LIVE LOAD ON SLAB = 5x5 x 100 = 2500#

ASSUME DEAD LOAD = 75#/□' LIVE LOAD = 100#/□'

IMPACT = 96#/□' TOTAL LOAD = 271#/□'

FROM T & M - PAGE 297 - TABLE 6. f_s = 15000 f_c = 600

SLAB = 3½" THICK. WEIGHT = 42.7#/□' % STEEL = .2470 □'

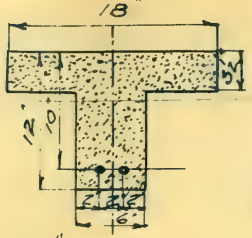
USE 1" Ø RODS - 3½" ON CENTER LINES FOR MIDDLE HALF AND 5" ON CENTER LINE TOWARD SUPPORTS

SCALE 1" = 1'-0"

S.C.A.

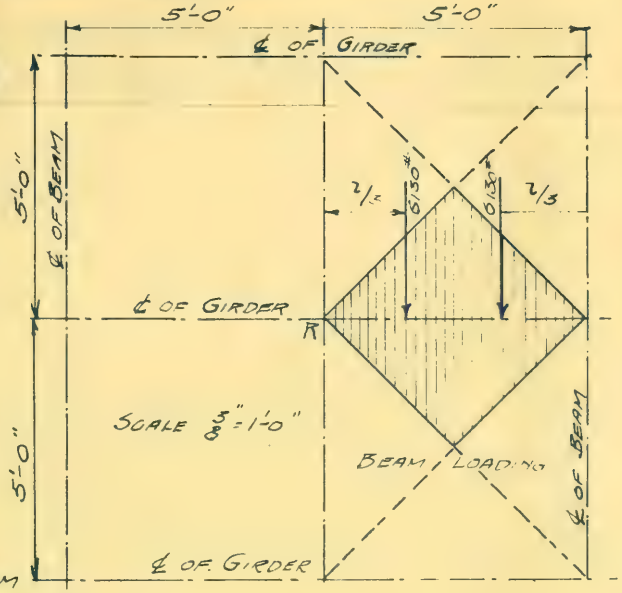
DESIGN OF BEAMS FOR CONCRETE

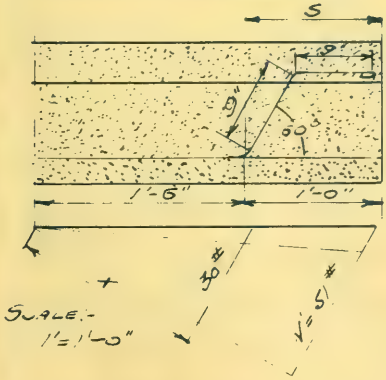
SECTION NORTH END.



2-$\frac{7}{8}$" ϕ RODS - 6'-0" TURNED AT 60° FOR STIRRUP

SCALE - 1" = 1'-0"





EACH BEAM TAKES ONE PANEL LOAD - ONE HALF PANEL LOAD ACTING THRU THIRD POINTS AS PER LOADING DIAGRAM

TOTAL SLAB LOAD ÷

D.L OF SLAB = 427 x 25 = 1170

L.L OF SLAB = 100 x 25 = 2500

IMPACT = 2460

TOTAL = 6130 #/□'

$R = \frac{6130}{2} = 3085\#$

$M = 3085 \times 1.0 = 4800$ '#

ASSUME :- b' = 6 D = 18' j = .10' t = 3½"

$A = \frac{M}{f_s(d - \frac{1}{3}t)} = \frac{58320}{15000(10 - \frac{3.5}{3})} = 0.741$ □"

USE 2-$\frac{9}{16}$" ϕ RODS AT 2'-0" ON CENTER

SHEAR = $\frac{3085}{6 \times 10} = 51\#$ □" FROM STIRRUP DIAGRAM

30 : 27 = 51 : X X = 45

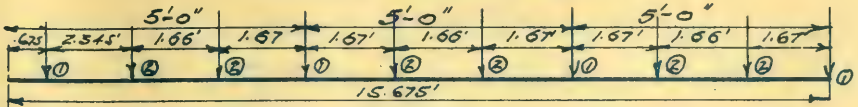
P = STIRRUP STRESS

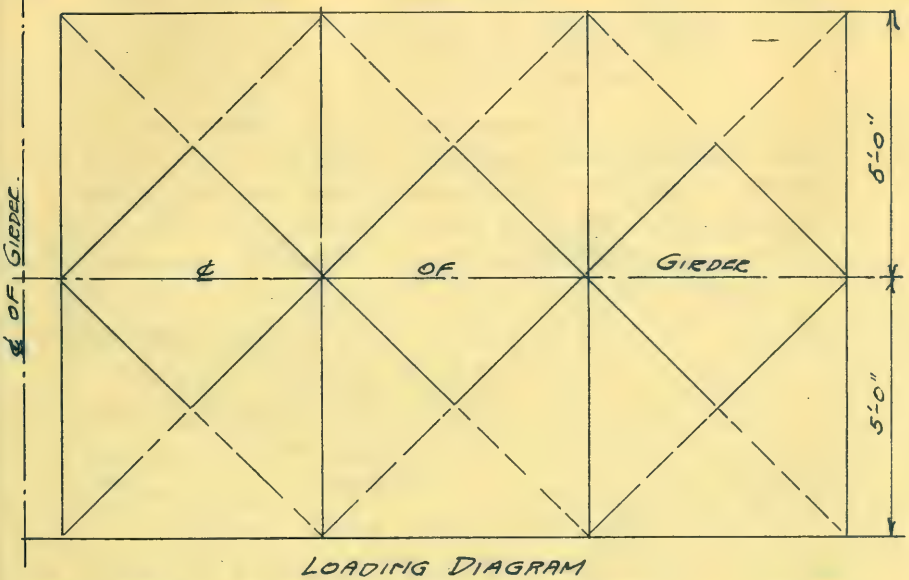
$P = v'bs \cos 60° = .5 \frac{V}{d} \cdot S = 0.5 \times \frac{3063}{10} \times 12 = 1840\#$/□"

AREA NEEDED = $\frac{1840}{5000} = .115$ □" USE 1-$\frac{7}{16}$" ϕ ROD 6'-0" L

S.C.A

DESIGN OF GIRDERS FOR CONCRETE SECTION NORTH END





LOADING DIAGRAM

BEAM REACTION AT ① AND GIRDER REACTION AT ②

TRACK LOAD :- END SHEAR FOR 32'-0" GIRDER (E-40) = 128,800 #/TRACK. TOTAL PER TRACK. FOR CHGO. BRIDGE LOAD $\frac{128800}{2} \times 0.325$ (See PLATE 2) = 20,900# IMPACT = 18,950#

END SHEAR DUE TO BEAM LOADS = 7 x 3065 = 21,455#

END SHEAR DUE TO SLABS = 6 x 3065 = 18390#

END SHEAR DUE TO WEIGHT OF SLABS $\frac{8.5 \times 6 \times 150 \times 5}{144} \times 3 = 796$

TOTAL = 80,491# END REACTION.

MOMENT AT CENTER FROM LOADING AS PER DIAGRAM = 12,114,600 "#.

ASSUME b = 72" $\frac{t}{d} = \frac{3.5}{24}$ p = 3%

PLATE 9 - T & M - PAGE 203 K = 0.325 J = 0.95

(FOR DIMENSIONS OF BEAM SEE PLATE 26

S.C.A.

DESIGN OF GIRDERS CONTINUED FROM PLATE #24

$A = \frac{M}{f_s \times jd} = \frac{12140600}{15000 \times 0.95 \times 24} = 35.4\square''$

$f_s = n\left(\frac{1-K}{K}\right) f_c \quad \therefore f_c = \frac{f_s}{n\left(\frac{1-K}{K}\right)} = \frac{15000}{15\left(\frac{1-0.325}{0.325}\right)} = 481$

$f_s' = n\left(\frac{K - \frac{d'}{d}}{K}\right) \times f_c = 15 \times \frac{0.325 - 4/24}{0.325} \times 481 = 3500$

$\frac{f_s - f_s'}{f_s} = \frac{1-J}{J'} \qquad J' = 1 - \frac{15000 - 3500}{15000} = 0.37$

$\therefore$ 37% REDUCTION NECESSARY.

AREA OF COMPRESSIVE STEEL = $0.37 \times 35.4 = 13.1\square''$

AREA OF TENSILE STEEL = $35.4 - 13.1 = 22.5\square''$

COMPRESSIVE STEEL = 8-1¼"Ø RODS - 2½' ON ℄.

TENSILE STEEL — 14-1¼"□ RODS 2½" ON ℄

SPACED 7 IN UPPER ROW - 7 LOWER ROW.

SHEAR.-

$V' = \frac{V}{bd} = \frac{80401}{24 \times 24} = 139\#\square'$

SEE STIRRUP DIAGRAM (26) FOR FOLLOWING DATA ON STIRRUPS

$\frac{80}{139} = \frac{X}{11.21} \quad X = 2'6'' \qquad P = .07 f_s = .07 \times \frac{80401}{24} \times .321$

$P = 7525\#$ AREA REQUIRED = $\frac{7525}{15000} = 0.5\square''$

TURN UP CENTER ROD TOP GROUD OF TENSILE 5'-0¾" FROM ℄ AT 45°

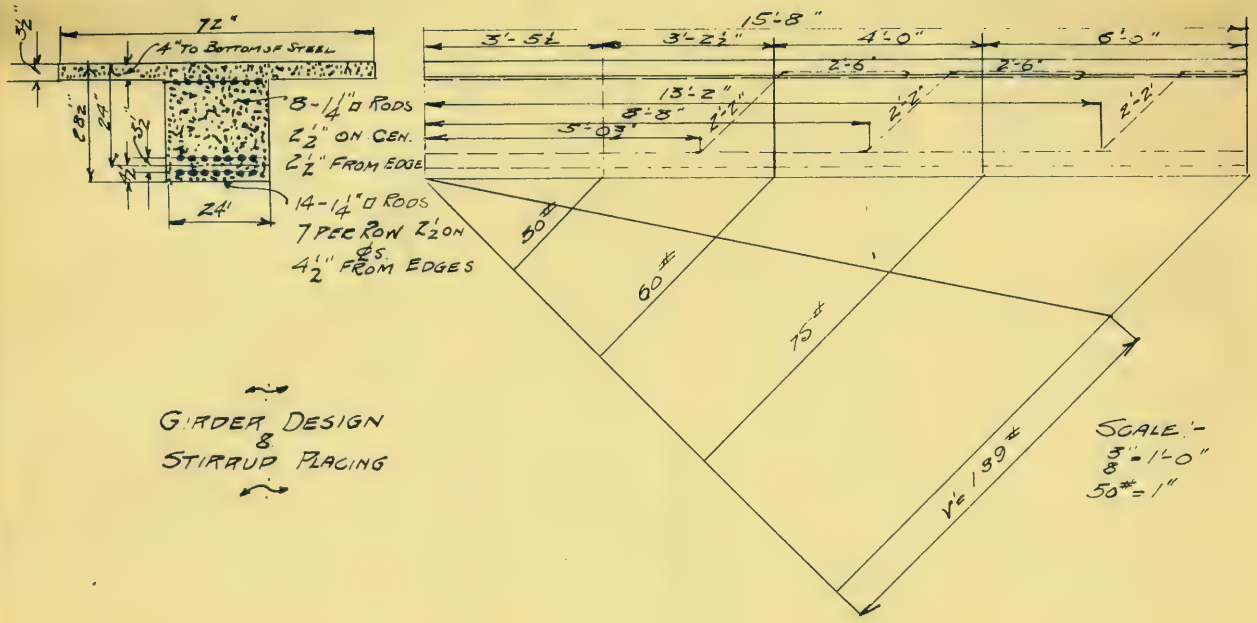
$P = .7 \times \frac{80401}{24} \times 4 = 9375\#$ AREA = $\frac{9375}{15000} = 0.625\square''$

TURN UP 2 RODS OF TOP ROW OF TENSILE STEEL ADJOINING MIDDLE 8'-8" FROM ℄ OF GIRDER.

$P = .7 \times \frac{80401}{24} \times 5 = 11700\#$ AREA = $\frac{11700}{15000} = 0.780\square''$

TURN UP 2 OUTSIDE TOP ROW OF TENSILE STEEL 13'-2" FROM ℄.

S.C.A.

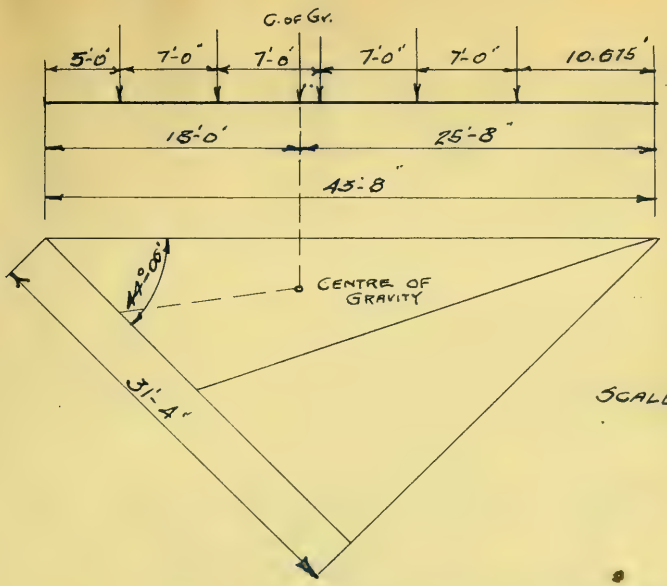


GIRDER DESIGN & STIRRUP PLACING

SCALE:-
3/8" = 1'-0"
50# = 1"

PLATE 26

6.CA.



SCALE $\frac{3}{8}$" = 1'-0"

LOADING DIAGRAM SIDE GIRDERS

DEAD LOAD = $\frac{30.4 \times 31.54 \times 42.7}{2}$ = 2030 #

LIVE LOAD = $\frac{30.4 \times 31.54 \times 100}{2}$ = 4760

GIRDER WEIGHT = $\frac{38.6 \times 25 \times 24 \times 150}{144}$ = 2410

BEAM WEIGHT = $\frac{36.2 \times 150 \times 8.5 \times 6}{144}$ = 1870

TOTAL = 11070

$R = \frac{11070 \times 25.675}{43.675}$ = 6500 # ∴ M = 6500 × 18 = 117,000 ft #

M = 117 000 × 12 = 1405,000 IN. #

$A = \frac{8M}{7 f_{sd}} = \frac{8 \times 1405000}{7 \times 15000 \times 24}$ = 4.45 "

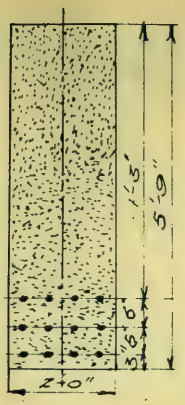
USE 5-1⅛" Ø RODS 2½" ON ℄.

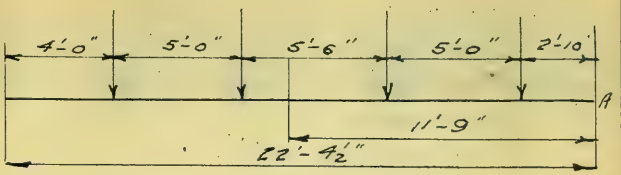
BEAM SECTION — 26½" × 14". —

SHEAR —

$v = \frac{V}{bd}$ = $\frac{6500}{14 \times 24}$ = 19.6. NO STIRRUPS NEEDED

GIRDERS BETWEEN COLUMNS





LOAD AT EACH POINT = 80491 #

$R_R = 80491 \frac{4+9+14.5+19.5}{22.375} = 169008$ #

C of G. $= \frac{80491 \times 47}{321960} = 11.75'$ From A

$M = 169000 \times 11.75 - 80491 \times (2.875+5) \times 12 =$

$M = 162500000$ IN #

$A = \frac{8 \times 162500000}{7 \times 15000 \times 60} = 20.65 \square''$

USE — 12 - 1½" Ø RODS - 6" ON ℄ —

BEAM = 69" x 24"

$v' = \frac{V}{bd} = \frac{169000}{60 \times 36} = 78.25$ #

STIRRUPS — FOR DETAILS SEE PLATE #20

$\frac{30}{78.25} = \frac{X}{7.83} \quad X = 3'$

$P = 0.7 \frac{V}{d} \times 15 = 0.7 \times \frac{169000}{60} \times 24 = 47{,}300$ #

$A = \frac{47300}{15000} = 3.15 \square''$

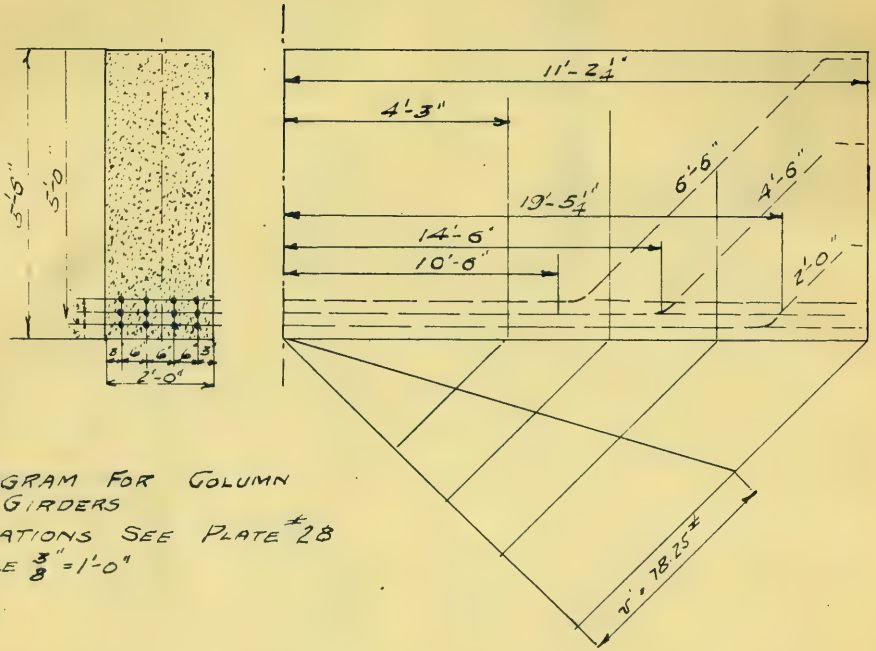
$P' = 0.7 \times \frac{169000}{60} \times 53.25 = 65600$ #

$A = \frac{65600}{15000} = 4.38 \square''$

FIRST SET OF STIRRUPS TURNED UP 5'-3" FROM CENTRE - USE 2 OUTSIDE TENSILE STEEL RODS IN LOWEST ROW

SECOND SET - USE 2 MIDDLE TENSILE STEEL BARS MIDDLE ROW TURNED UP 7'-3" FROM CENTER.

THIRD SET - USE 2 OUTSIDE TENSILE STEEL BARS IN TOP ROW - TURN UP AT $9'-8\frac{5}{8}"$ FROM THE CENTER



STIRRUP DIAGRAM FOR COLUMN GIRDERS

FOR CALCULATIONS SEE PLATE #28

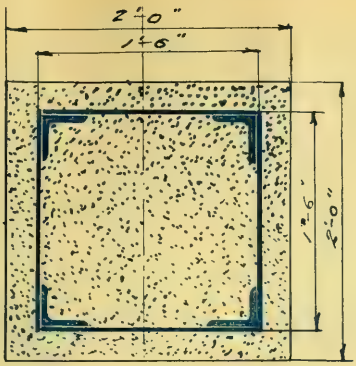
SCALE $\frac{3}{8}$" = 1'-0"

SC.4

PLATE 29.

COLUMN DESIGN FOR CONCRETE

SECTION NORTH END.



ASSUME $f_c = 400$ $f_s = 15 f_c$ $P' 8\%$

$f_s = \frac{15 \times 400}{p} = 6000$

$A = \frac{f_c (1+(n-1)p}{} = \frac{338000}{400 \times (1+1.2)} = 400\square''$

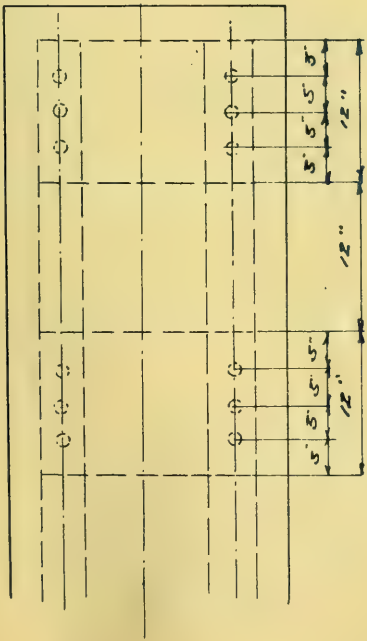
$358000^{\#}$ = LOAD SUPPORTED BY A CENTRAL COLUMN

$A_s = p. 8\%$ $A = .08 \times 400 = 32\square''$

$A_c = \frac{P - f_c p}{f_c} = \frac{338000 - 6000 \times 32}{400}$

$A_c = 365\square''$ NEEDED USE $576\square''$

$P_c = \frac{P'}{1+(n-1)p} = \frac{338000}{2.12} = 153500^{\#}$



COLUMN SECTION :—

CONCRETE = 24" x 24"

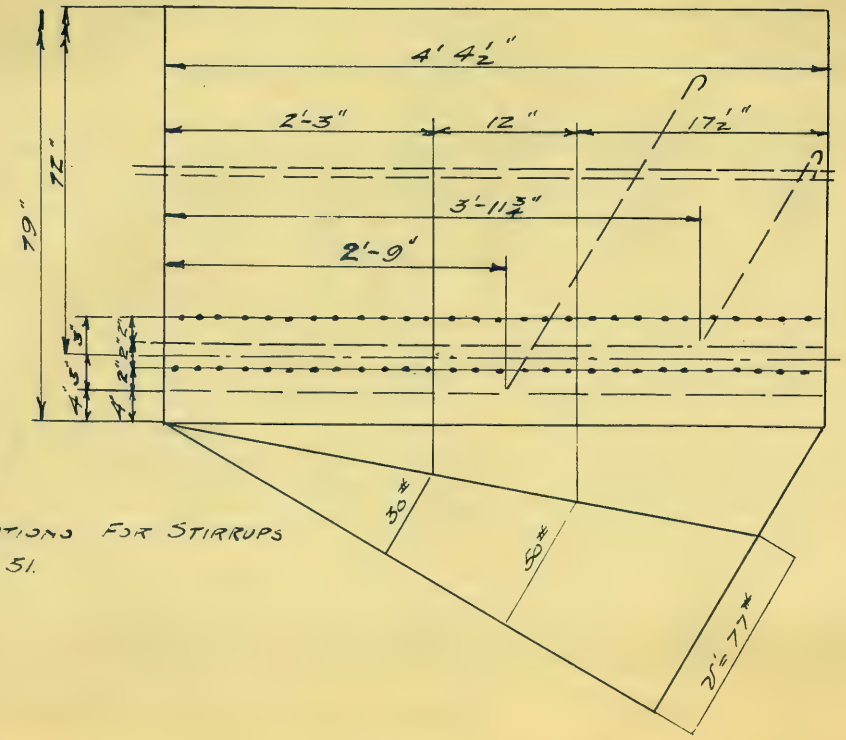
REINFORCING = 4 LS - $3\frac{1}{2}' \times 3\frac{1}{2}' \times \frac{3}{8}$

TIED BY PLATES $24'' \times \frac{3}{8}'' - 1'-0''$

SPACED 2'-0" ON CENTER LINE.

S.C.A.

Stirrups Design
For
Girder Columns
— Foundation —

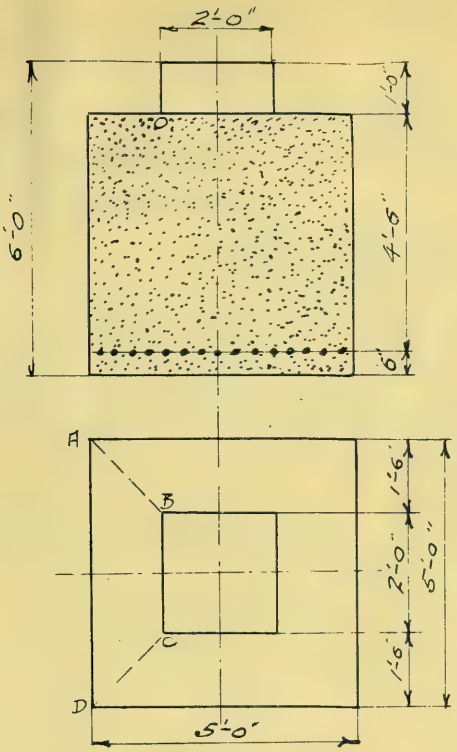


For Calculations For Stirrups
See Plate 51.

Plate 31-A.

S.C.A.

CONCRETE COLUMN FOUNDATIONS



LOAD THRU COLUMNS = P = 338000#

BEARING OF FOUNDATION STRATA = 14,400#/□"

AREA REQ'D = $\frac{338000}{14400}$ = 230□" BASE = 5'-0" x 5'-0"

CENTER OF GRAVITY OF TRAP. ABCD. $\frac{15}{3} \times \frac{2(2+5}{2+5} = .645'$

MAT'O = 169000 x 12 x .85 = 1,720,000 IN#

A = $\frac{1720000 \times 8}{7 \times 15000 \times 60}$ = 2.72 □" STEEL NECESSARY

USE 1" Ø RODS $4\frac{1}{2}$" ON ℄ – 4'-6" LONG

SHEAR —

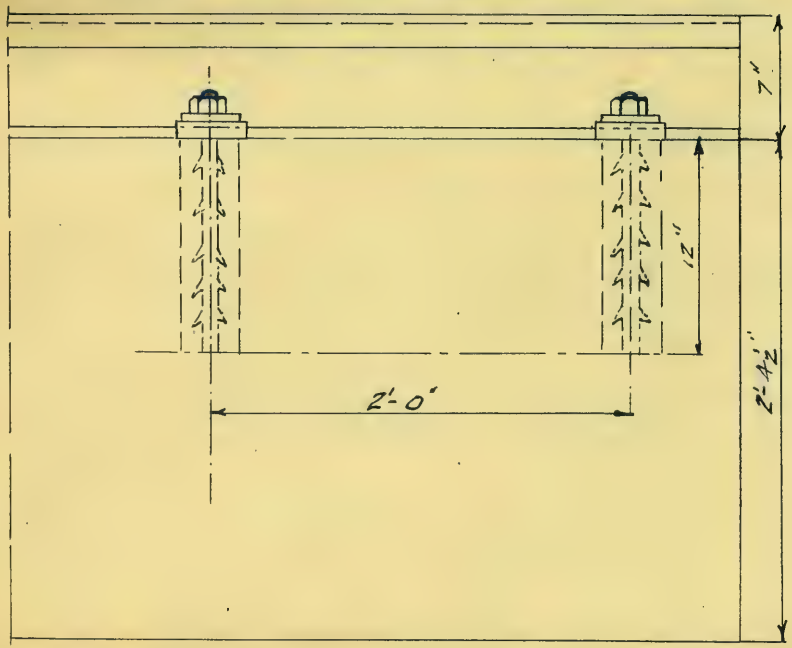
v' = $\frac{V}{bd}$ = $\frac{139000}{60 \times 66}$ = 47# ALLOWED = 30#

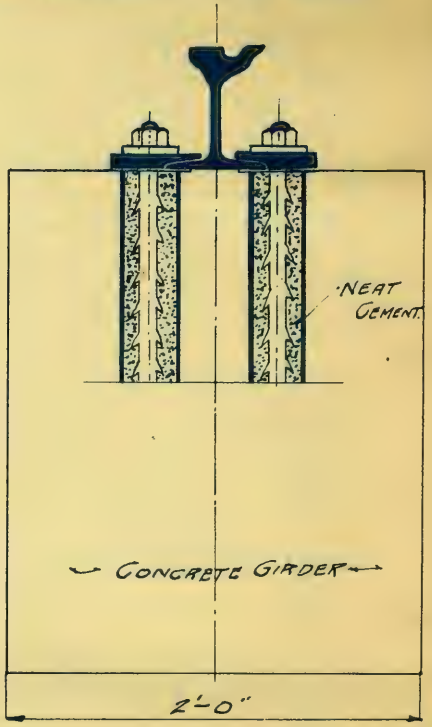
TURN UP EVERY FOURTH ROD 60° – 1'-0" FROM CENTER

S.C.A.

RAIL FASTENING IN CONCRETE.

3" PIPES PLACED IN CONCRETE 1'-0" LONG - 2'-0" ON CENTERS. 1" BURRED BOLTS SUNK INTO PIPES AND BROUGHT TO GRADE. FILL PIPE WITH NEAT CEMENT AND ADJUST TO CONFORM WITH TRACK ELEVATION



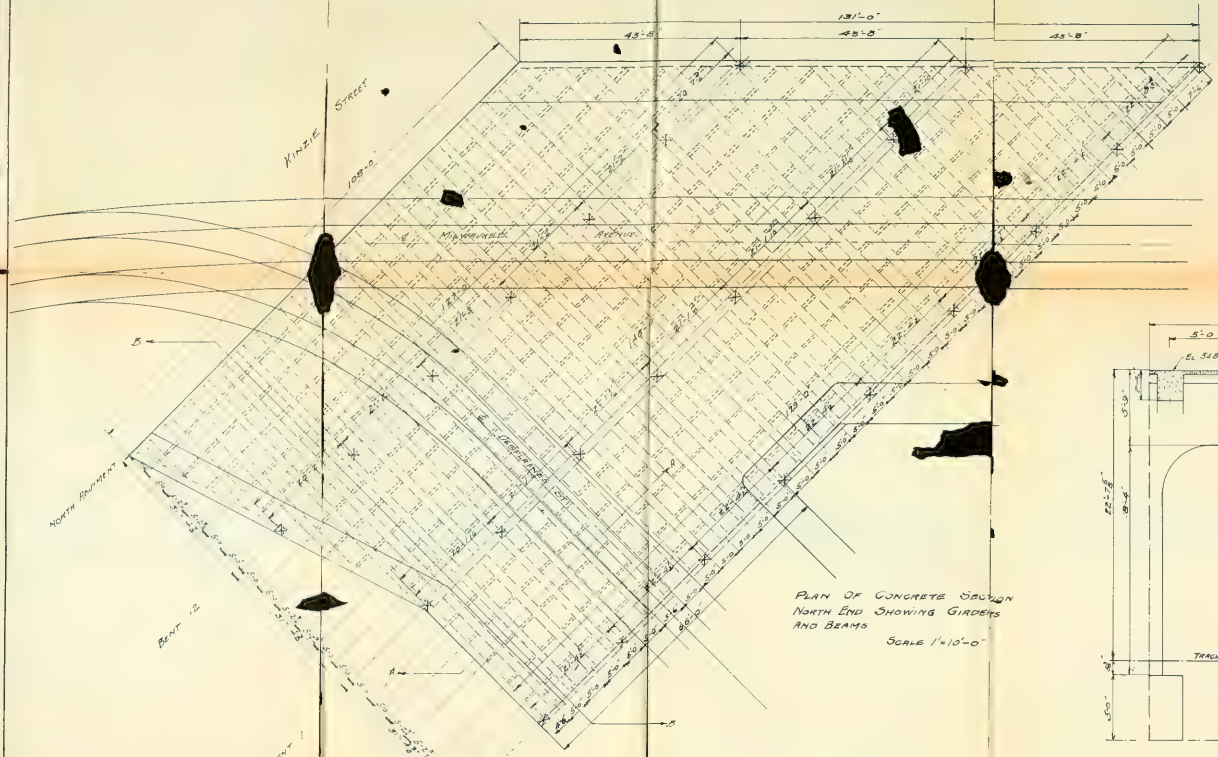


SCALE 1½" = 1'-0"

S.CA.

PLATE 33.

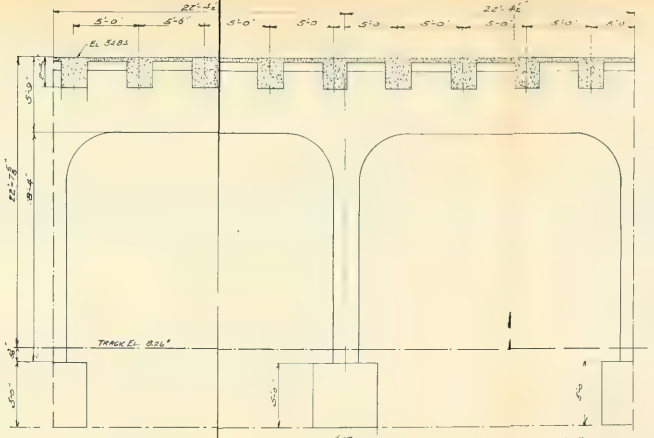
PLATE 34



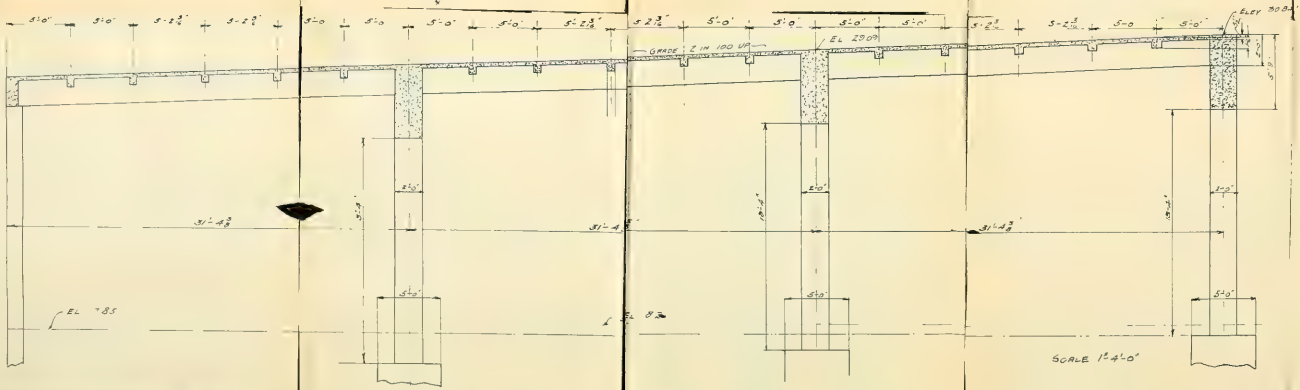
PLAN OF CONCRETE SECTION NORTH END SHOWING GIRDERS AND BEAMS

SCALE 1"=10'-0"

TYPICAL SECTION THRU A-A' SHOWING CROSS AND SPAN GIRDERS BEAMS AND SLABS

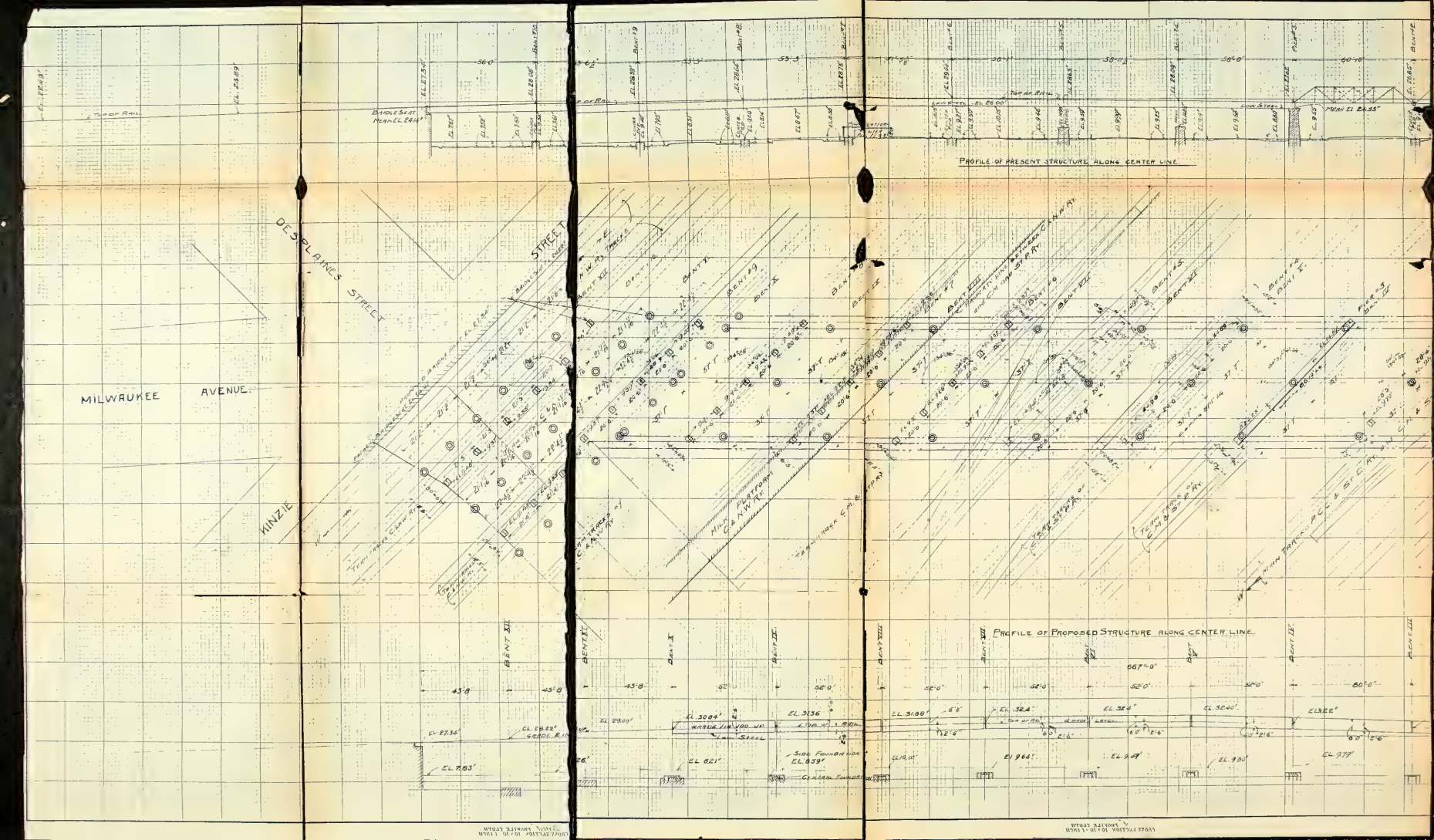


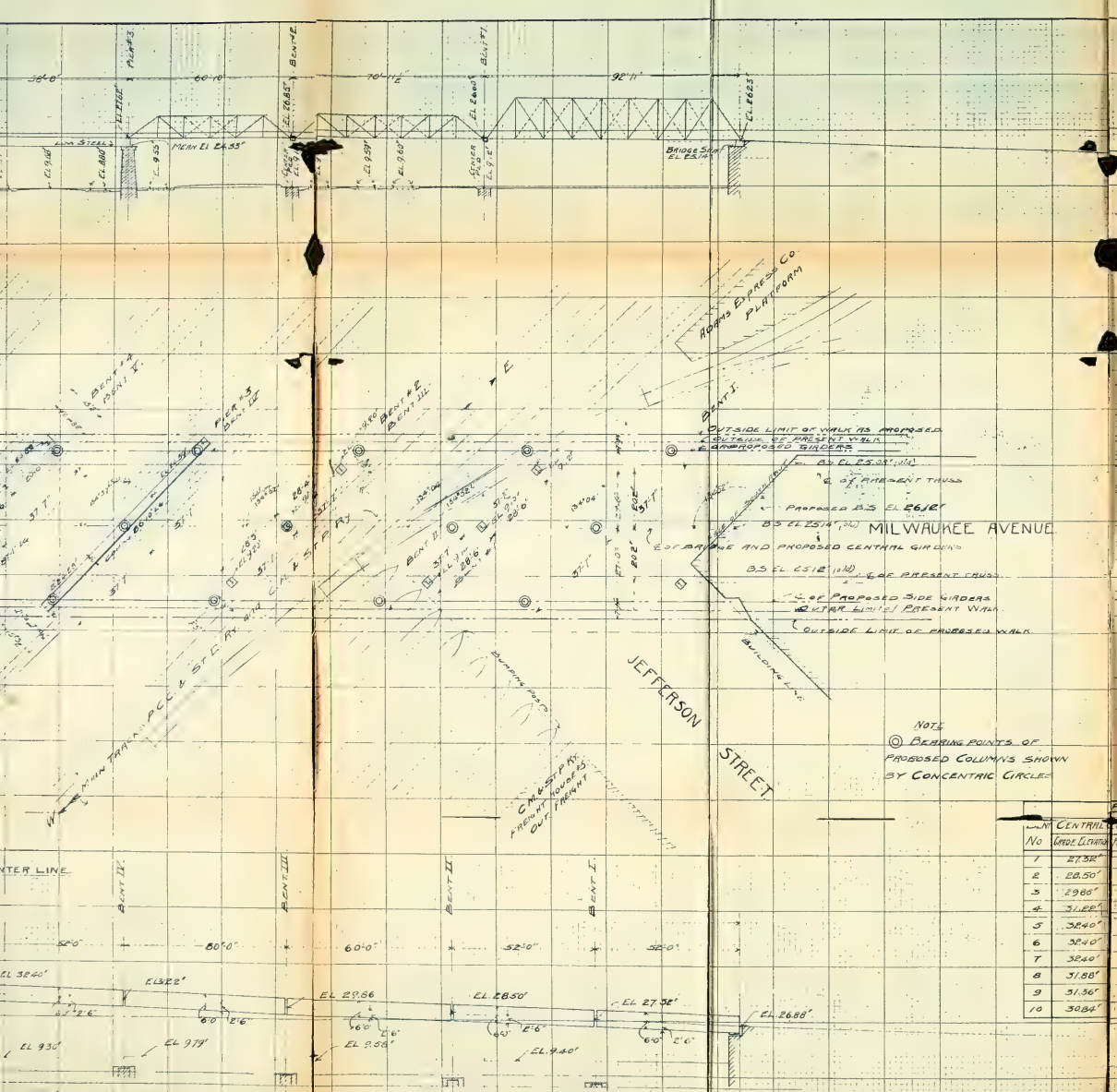
TYPICAL SECTION THRU BB.



SCALE 1"-4'-0"

ARMOUR INSTITUTE OF TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT
THE RECONSTRUCTION OF THE MILWAUKEE
AVE VIADUCT — CHICAGO ILL
DESIGN OF CONCRETE SECTION NORTH END
SCALE 1"=4'-0" DRAWN BY E. Sanderson William Beach


DES PLAINES STREET
MILWAUKEE AVENUE
HINZIE
PROFILE OF PRESENT STRUCTURE ALONG CENTER LINE
PROFILE OF PROPOSED STRUCTURE ALONG CENTER LINE
667'-0"



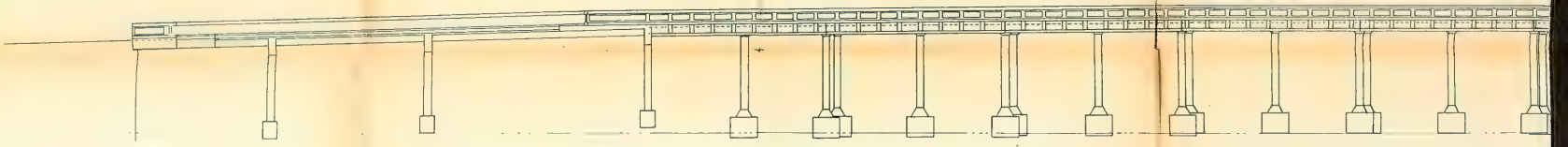
NOTE
◎ BEARING POINTS OF PROPOSED COLUMNS SHOWN BY CONCENTRIC CIRCLES

VICINITY MAP

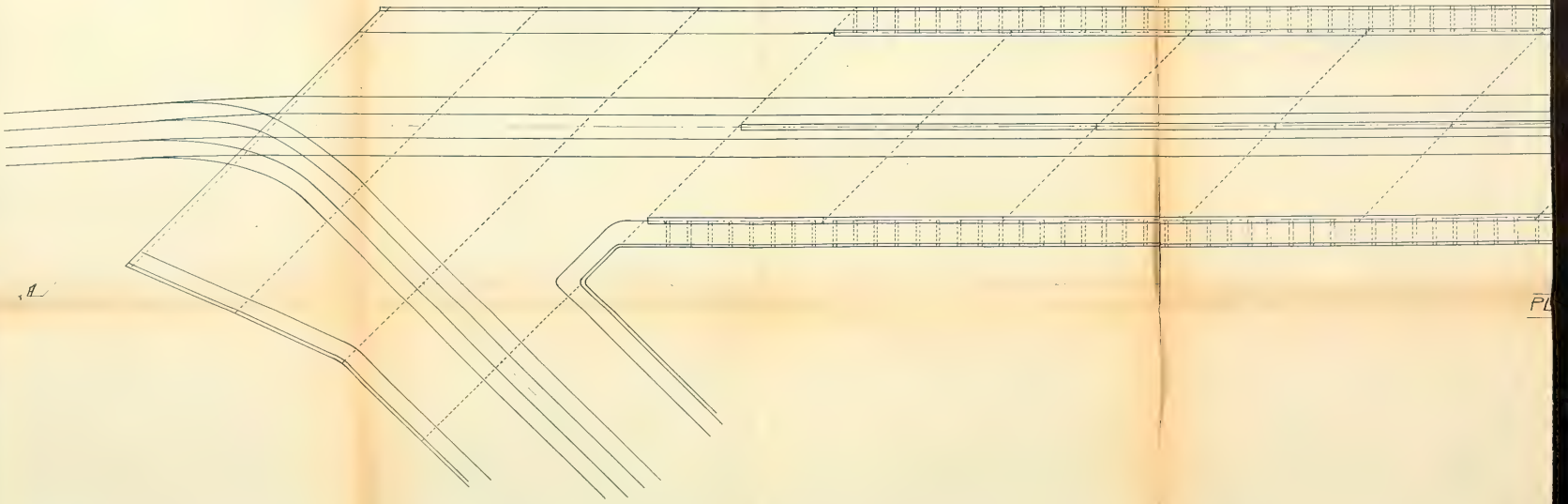
ELEVATIONS of COLUMN FOUNDATIONS

Col. No	CENTRAL Grade Elevation	CENTRAL Footing Elev	Intermediate Grade Elev	Intermediate Footing Elev	Outside Grade Elev	Outside Footing Elev	Elevation of Track	Clearance
1	27.32'	1.36'	27.32'	1.49'	9.40'		9.40'	17.92'
2	28.50'	2.54'	28.50'	2.67'	9.38'		9.38'	18.92'
3	29.86'	3.90'	29.86'	4.03'	9.79'		9.79'	20.07'
4	31.22'	5.26'	31.22'	5.39'	9.30'		9.30'	21.92'
5	32.40'	6.44'	32.40'	6.60'	9.30'		9.30'	23.10'
6	32.40'	6.44'	32.40'	6.60'	9.44'		9.44'	22.93'
7	32.40'	6.44'	32.40'	6.60'	9.64'		9.64'	22.76'
8	31.88'	5.92'	31.88'	6.08'	10.02'		10.02'	21.86'
9	31.36'	5.40'	31.36'	5.56'	8.53'		8.53'	22.77'
10	30.84'	4.88'	30.84'	5.04'	8.21'		8.21'	22.63'

ARMOUR INSTITUTE OF TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT.
SURVEY FOR THE RECONSTRUCTION OF THE MILWAUKEE AVENUE VIADUCT.
CHICAGO, ILL.
SCALE 1"=20'.
MAY, 1911.
William Bean

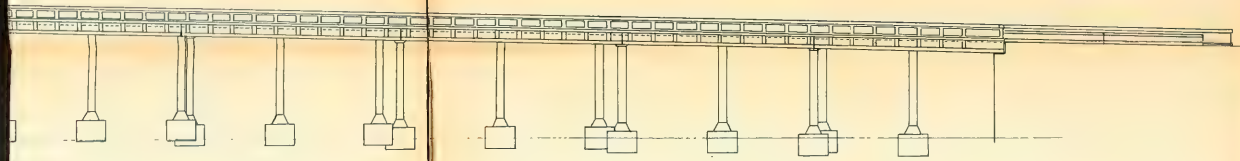


ELEVA

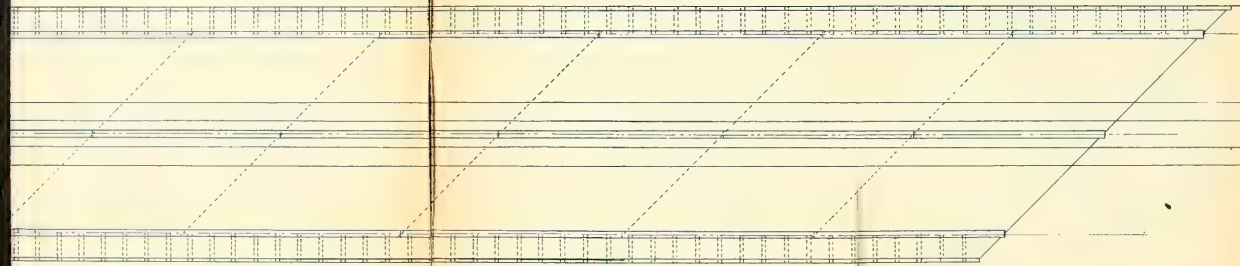


PL

PLATE 3



TION THRU A-A'



AN.

ARMOUR INSTITUTE of TECHNOLOGY.
CIVIL ENGINEERING DEPARTMENT.
GENERAL
VIEW OF
PLAN & PROFILE
OF THE
MILWAUKEE AVENUE VIADUCT.
Scale 1"=16'
May 26, 1912